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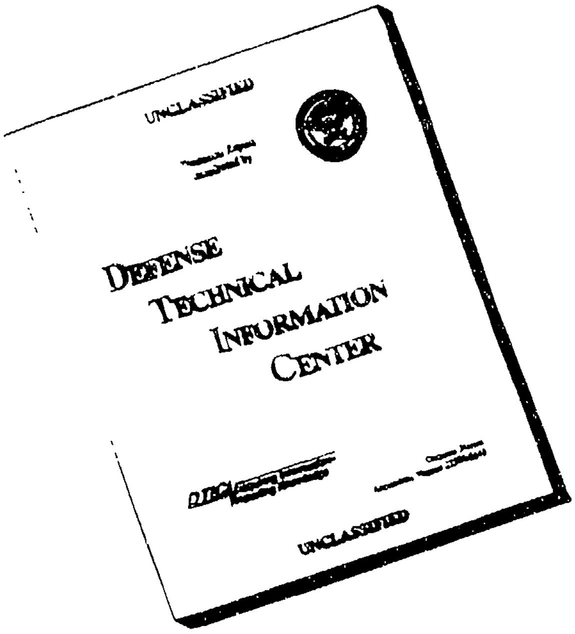

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LITIGATION TECHNICAL SUPPORT AND SERVICES
ROCKY MOUNTAIN ARSENAL

BIOTA REMEDIAL INVESTIGATION
FINAL REPORT
VERSION 3.2
VOLUME I

May 1989
Contract Number DAAK11-84-D0016
Task Number 9

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THE PURPOSE OF THE BIOTA REMEDIAL INVESTIGATION REPORT IS TO PRESENT THE CURRENT NATURE AND EXTENT OF CONTAMINATION IN BIOTA ON RMA. THE REPORT INTEGRATES KNOWN HISTORICAL INFORMATION, THE RESULTS OF PREVIOUS INVESTIGATIONS, AND RESULTS OF CURRENT PROGRAMS.

THE REPORT IS DIVIDED INTO THE FOLLOWING SECTIONS:

1. GENERAL BACKGROUND INFORMATION ON RMA CONTAMINATION AND PAST INVESTIGATIONS
2. DESCRIPTION OF THE PHYSICAL ENVIRONMENT, REGIONAL BIOTA, AND BIOTA WITHIN THE ARSENAL; IDENTIFICATION OF IMPORTANT BIOLOGICAL COMPONENTS AS A BASIS FOR EVALUATING CONTAMINATION
3. SUMMARY OF THE METHODS USED IN THIS ASSESSMENT
4. DATA ON THE TYPES AND CONCENTRATIONS OF CONTAMINANTS IN RMA BIOTA
5. ASSESSMENT OF THE DISTRIBUTION AND CONCENTRATION OF CONTAMINANTS IN BIOTA AND ASSOCIATED ENVIRONMENT TO EVALUATE PATHWAYS FOR CONTAMINANT MOVEMENT

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Biota Remedial Investigation
Final Report
(Version 3.2)
Volume I

May 1989
Contract Number DAAK11-84-D0016
Task Number 9

Prepared by
ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.

Prepared for
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EXECUTIVE SUMMARY

Biota assessment studies were initiated to determine the nature and extent of Rocky Mountain Arsenal (RMA) contamination in biota. Studies were developed in conformance with the requirements of current applicable legislation [e.g., Comprehensive Environmental Response, Compensation, and Liability Act as amended to the Superfund Amendments and Reauthorization Act (together refered to as CERCLA)], and followed the guidance for such studies provided in the National Contingency Plan (NCP) and Environmental Protection Agency (EPA) documents for the conduct of Remedial Investigations (RIs).

As such, these biota studies identify the impact of RMA contamination on the plants and animals found at RMA in order to generate information that will be of assistance in determining the appropriate form that the remediation of the site should take in accordance with CERCLA. These studies did not inventory or discuss the management of the many species found at RMA and in particular, did not focus upon the RMA biota that are not affected by contamination. The U.S. Fish and Wildlife Service (FWS) will address these subjects separately over the coming months. Nor are these studies intended to anticipate or to be co-extensive with the CERCLA Natural Resource Damage Assessment (NRDA) process that will commence at RMA upon completion of the Onpost Remedial Investigation (RI). While certain data gathered in the biota assessment may warrant consideration in the NRDA, the use that will ultimately be made of such data necessarily varies depending on whether it was assembled for purposes of the NCP NRDA. As explained above, it is for the former purposes that the biota assessment and the report were prepared.

Here, the Army's assessment was conducted in two phases. Phase I focused on the acquisition and review of available data, conduct of brief site visits, and evaluation of pertinent information from all sources. It provided a preliminary determination of biota contamination and developed, as necessary, a plan for obtaining additional relevant information. A review of the extensive body of information on contamination in RMA biota during this phase indicated the need for a comprehensive evaluation of current contamination to supplement historical information on the effects of selected chemicals at various locations. This comprehensive evaluation was done during Phase II.

Phase II of the biota assessment was designed to characterize regional and study area biota, to augment and update past studies, and to provide a current comprehensive assessment of biota contaminant levels and effects in conformance with current regulatory requirements. Scoping and design of the investigation were partially determined by the types and concentrations of contaminants documented to be still present in abiotic components of the biosphere, that portion of the environment supporting life. The project scope was discussed and modified by the Biota Assessment Working Group (formerly the Biota Assessment Subcommittee) of the RMA Committee that met periodically throughout the study. The committee was composed of representatives of the federal government (U.S. Army and their contractors, Environmental Science and Engineering, Inc., and the FWS, the State of Colorado (Colorado Division of Wildlife), and Shell Oil Company (i.e., Shell and their contractors, Morrison-Knudsen Engineers, Inc.). The EPA received copies of all meeting minutes. The resulting program studied selected populations, and addressed the contaminants of concern to biota, potential adverse effects of contaminants on biota, the pathways of contaminant movement to and through biological systems, and analyzed tissues from selected species to document current levels of specific target analytes.

During Phase II, quantitative vegetation, wildlife, and aquatic studies were conducted on RMA and at offpost sites used as controls to characterize regional and study area biota. Population surveys of black-tailed prairie dogs, earthworms, grasshoppers, snails were conducted. Reproductive success studies were performed for mallards, ring-necked pheasants, and American kestrels. Acetylcholinesterase inhibition studies were conducted on American kestrels, ring-necked pheasants, prairie-dogs, cottontails, and several samples of chance. In addition, several studies of general abundance of particular species groups were done to enable characterization of current RMA biota. An investigation of bald eagle distribution, temporal occurrence, feeding habits, and habitat use was initiated following the discovery of a bald eagle winter roost on RMA in December 1986. Results showed that up to 28 bald eagles at a time forage on RMA and use the roost.

Winter food consisted primarily of prairie dogs and rabbits, mostly obtained by driving other raptors off of kills. Black-footed ferret studies were also conducted at the request of the FWS, but no ferrets were found. Studies of prairie dog populations were conducted to quantify the prey base for eagles and other predators, and to determine possible contaminant pathway effects on these species.

Screening of documented RMA contaminants produced a list of 39 contaminants of potential concern to biota. Of these, seven were determined to be major contaminants of concern on the basis of toxicity, environmental persistence, spatial distribution, and other criteria. These chemicals are arsenic, mercury, dibromochloropropane, and the organochlorine pesticides aldrin, dieldrin, endrin, and isodrin. Pathways for these contaminants were constructed to evaluate potential environmental effects (e.g., effects on species at higher trophic levels and the overall structure and function of food webs). The remaining 32 other contaminants of concern were subjected to toxicity assessment. On the basis of these evaluations, contaminant analyses were conducted on five of the major contaminants of concern (arsenic, mercury, aldrin, dieldrin, and endrin) in biological tissues. DBCP was not included as a contaminant analyte because it does not bioaccumulate significantly, while isodrin is an analog of endrin and is converted metabolically to that compound. Analyses were also performed for 1,1-dichloro-2,2-bis (4-chlorophenol)-ethylene/dichlorodiphenyltrichloroethane (DDE/DDT) in selected species where these chemicals were implicated in adverse effects (such as reduction in avian reproductive success). Contaminant levels were measured in organisms from sites of known or suspected contamination and from onpost and offpost control sites.

The study design consisted of sampling in contaminated and control sites, but varied depending on the mobility of the species being surveyed. For species with restricted mobility (e.g., cottontails, prairie dogs, etc.), sampling was conducted in major sites of contamination on RMA, in control (uncontaminated) sites on RMA, and in offpost control sites. For highly mobile species that could be exposed to multiple sites of contamination on RMA yet also occupy uncontaminated portions of RMA (e.g., mule deer), sample design grouped samples as RMA (contaminated site) and offpost controls.

Tissues to be analyzed for the seven compounds just mentioned were collected from control and contaminated areas on RMA for less mobile species, and from RMA and offpost control areas for more mobile species. The species to be sampled were selected to represent various trophic levels, possible pathways to humans, species of particular state or federal concern, and/or species of special ecologic interest. Specifically, from the terrestrial and semi-aquatic ecosystem two species (morning glory, common sunflower), two invertebrate species groups (grasshoppers, earthworms), three bird species (mallards, ring-necked pheasants, American kestrels), and three mammal species (black-tailed prairie dogs, desert cottontail, mule deer) were collected for tissue analyses. From the aquatic ecosystems, plankton, aquatic macrophytes, and five fish species (largemouth bass, bluegill, northern pike, fathead minnows, black bullhead) were collected for tissue analysis. In addition, miscellaneous species collected as samples of chance or by the FWS in prior years were used for tissue analysis. On RMA most samples from non-aquatic contaminated areas were collected from Section 26, 36, South Plants (portions of Sections 1 and 2) and 31, while those for onpost controls (uncontaminated areas) were from Sections 5, 7, 8, 19, 20. Samples of more widely ranging species (American kestrels, raptors, mammalian carnivores, mallards, waterfowl, mourning doves, ring-necked pheasants, and mule deer) were collected from more widespread portions of RMA, and controls were collected from offpost. Samples of aquatic species representing contaminated areas were collected from Lake Mary, Lake Ladora, Lower Derby Lake, North Bog, while control samples were collected from McKay Lake, which is offpost. With minor exceptions all tissues collected were analyzed for aldrin, dieldrin, endrin, DDT/DDE, mercury, and arsenic with minor exceptions related to their appropriate potential pathways. Arsenic and DDE/DDT were not sampled in all tissues from all sites because of their absence above background in the abiotic environment of some sites and (for arsenic) the low capacity to bioaccumulate.

Contaminant studies of terrestrial plants (morning glory, common sunflower) found that levels of arsenic in sunflowers and in one morning glory from Basin A were within the range that could produce phytotoxic effects, but no such effects were detected in the plants sampled. Sensitivity to arsenic might be a contributing factor to the reduced plant diversity in some areas, but this could not be measured due to the high levels of human disturbance. Dieldrin levels were detected in both plant species sampled, but not at levels that could be expected to adversely affect plants. The endrin levels found in one sunflower sample from Basin C was lower than any documented levels in the diet of birds that are known to produce adverse effects. Dieldrin and endrin bioaccumulate and could produce effects higher in food chains.

Invertebrate (aquatic snail, grasshopper, earthworm) population studies did not indicate any reduction on RMA attributable to contaminants. Mercury was found in grasshoppers and earthworms at levels that exceed the recommended acceptable dietary level for birds, and could therefore produce adverse effects in birds such as kestrels and young pheasants that consume grasshoppers or other species that consume earthworms. Aldrin, dieldrin and endrin in grasshoppers and dieldrin and endrin in earthworms from RMA sites of contamination were present at levels that could, through biomagnification, be hazardous to species at higher trophic levels in terrestrial food webs. Arsenic was detected in both invertebrate species groups, but this compound does not tend to bioaccumulate and no adverse effect levels are documented for invertebrates.

Black-tailed prairie dog studies found no effects of contamination on population density. Juvenile-adult ratios were significantly lower in RMA prairie dog towns than on nearby offpost control sites. These differences appeared to be the result of normal environmental factors rather than RMA contamination. Organochlorine pesticides in prairie dogs of Section 36 on RMA were at levels that could be hazardous to eagles, other raptors, and mammalian predators. Dieldrin was the only contaminant analyte detected in cottontails, but it was present at low concentrations well below the FDA action level.

Blood samples taken from bald eagles on RMA did not indicate the presence of any of the seven RMA contaminant analytes above levels found offpost. A single bald eagle embryo from Barr Lake showed the presence of both dieldrin and DDE, but apparently from sources near Barr Lake and not RMA, based on casual observations of the adult eagles' foraging. Tissue samples from two golden eagles found dead on RMA showed contaminant levels below those known to produce adverse effects in birds.

Dieldrin was found to be the principal contaminant in the tissue of other raptor species. Lethal levels of dieldrin were found in ferruginous hawk, red-tailed hawk, and great-horned owl brains from animals collected on RMA. Necropsy data showed that these individuals exhibited typical signs of pesticide poisoning. Knowledge of the foraging range, feeding habits, and seasonal use patterns of these species indicate that the probable source(s) of this contamination were within the boundaries of RMA.

Studies of avian reproductive success indicated that the American kestrel had significantly reduced reproductive success apparently attributable to organochlorine pesticide contamination from RMA sources, and that reproduction in mallards was also inhibited on RMA. Samples of mallards, and kestrels from RMA contained mercury, dieldrin, and DDE. Some offpost control samples of these two species contained mercury and DDE. Some pheasant samples from RMA and from offpost controls contained arsenic, dieldrin, and DDE. Some pheasants, mourning doves, and waterfowl from the interior portions of RMA contained tissue levels of dieldrin in excess of analogous FDA action levels.

Only one of 14 mule deer collected on RMA showed detectable levels of one of the seven RMA contaminant analytes, dieldrin. The sample was taken from an animal accidentally killed between Basin A and the South Plants. Tissue levels of dieldrin in one coyote found dead of unknown causes on RMA fell at the lower end of the range known to be lethal in dogs.

Dieldrin values showed increasing concentrations in moving from lower trophic levels (plants and insects) to higher levels (raptors and mammalian predators), thus providing evidence to support the bioaccumulation of this organochlorine pesticide through the terrestrial food chain.

Data from analyses of aquatic plant, plankton, and fish samples collected by Morrison-Knudsen Engineers (MKE) from the Lower Lakes and North Bog on RMA and from offpost control sites indicated that some aquatic communities on RMA are still contaminated with organochlorine pesticides and mercury. Results of MKE investigations are in general agreement with the findings of previous studies that demonstrated the bioaccumulation of these contaminants in aquatic communities on RMA.

The available data on abiotic components of the environment show that arsenic, mercury, and the organochlorine pesticides aldrin, dieldrin, and endrin are currently present in the soil and/or water at some contamination sites on RMA at levels that could result in a variety of lethal and sublethal effects on biota. Dieldrin is of greatest concern because of its toxicity, persistence, spatial extent on RMA, occurrence in aquatic and terrestrial ecosystems, and capacity to bioaccumulate in regional food webs. While arsenic and mercury are also present in the RMA environment, the extent and severity of adverse effects in biota appear to be less than those of the organochlorine pesticides.

Acetylcholinesterase (AChE) inhibition studies were conducted on the brains of animals found dead on RMA and on selected species collected for contaminant analysis. No AChE inhibition was detected in the mallard, pheasant, raptor, and cottontail rabbit brains analyzed. AChE inhibition was not detected in prairie dogs from Section 36, but significant AChE inhibition was detected in prairie dogs from the Toxic Storage Yard on RMA. Inhibition appeared to be the result of heavy metals naturally occurring in near localized rock outcrops and not the result of RMA contamination.

The pathway analyses of the major RMA contaminants were conducted in order to evaluate the relationship between the abiotic (physical) and biotic components of the environment. Pathway analyses and applicable EPA ambient water quality criteria establish acceptable levels of the major contaminants that can occur in the abiotic environment without resulting in detectable adverse effects on the biota.

Preliminary application of these acceptable levels as potential site-specific criteria indicates that remediation could be necessary to restore certain sites on RMA to acceptable contaminant levels. Information on the concentration and distribution of RMA contaminants in physical media will be evaluated on the basis of these levels considered acceptable for biota as well as on criteria from other components of the RI. The spatial extent of contamination that must be cleaned up will subsequently be defined in Study Area Reports (SARs).

The presence on RMA during winter months of an endangered species, the bald eagle, is an additional biological consideration that will be addressed during feasibility studies, interim actions, and long-term site remediation. Ongoing comprehensive monitoring, U.S. Fish and Wildlife Service regional bald eagle studies, the establishment of a bald eagle management area on RMA, and related investigations will continue to produce information needed to evaluate biological concerns during these remediation activities.

This document is a formal RI product in accordance with the Federal Facilities Agreement among the U.S. Army, Department of Interior, Health and Human Services, the EPA, Shell Oil Company, the U.S. Department of Justice, and the Settlement Agreement between the United States and Shell, the RMA Technical Program Plan (TPP), and the June 1985 RI Guidance Document (EPA). This document has been prepared to fulfill the requirements of defining the nature and extent of RMA contamination in biota as required by CERCLA and the NCP. Information contained in this report will be evaluated in conjunction with information from the Study Area Reports (SARs) and RI documents for other media during the Feasibility Study to formulate response objectives at RMA.

1.0 INTRODUCTION

The purpose of the Biota Remedial Investigation Report is to present the Army's Remedial Investigation (RI) results for the assessment of Rocky Mountain Arsenal (RMA) contamination in relation to biota. This document is a formal remedial investigation (RI) product in accordance with the proposed Consent Decree (1988), the RMA Technical Program Plan (TPP) (PMO, 1988, RIC#88131R01), and the June 1985 RI Guidance Document (EPA). The seven completed RI Study Area Reports (SARs), along with the RI media reports for air, biota, buildings, and water were conducted in accordance with the requirements of defining the nature and extent of contamination as required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Superfund Amendments and Reauthorization Act (SARA), and the National Contingency Plan (NCP). The Biota RI Report integrates known historical information, the results of previous investigations, and the current RI programs for biota to provide a synopsis of contamination at RMA in relation to vegetation, wildlife, and aquatic resources as required under Contract Number DAAK11-84-D-0016.

Rocky Mountain Arsenal (RMA) has been a U.S. Army installation for over four decades. Covering over 6,900 hectares (ha; 17,000 acres), RMA lies in southern Adams County about 16 kilometers (km; 10 miles) northeast of downtown Denver, just north of Stapleton International Airport (Figure 1.1-1). Present activity at RMA is limited to land management, security, technical investigations of chemical contamination sources and current distribution, and interim response actions for selected problem areas. The data from these investigations will ultimately guide remediation.

In this document, Section 1.0 presents general background information on RMA contamination and summarizes past investigations. Section 2.0 provides a description of the abiotic environment, regional biota, and biota within the RMA study area and identifies important biological components as a basis for evaluating RMA contamination. Section 3.0 is a brief summary of the methods used in this biota assessment. A detailed description of study methods is provided in the Task 9 Biota Assessment Final Technical Plan (ESE, 1988, RIC#88243R05). As part of the biota assessment, tissues from animals found

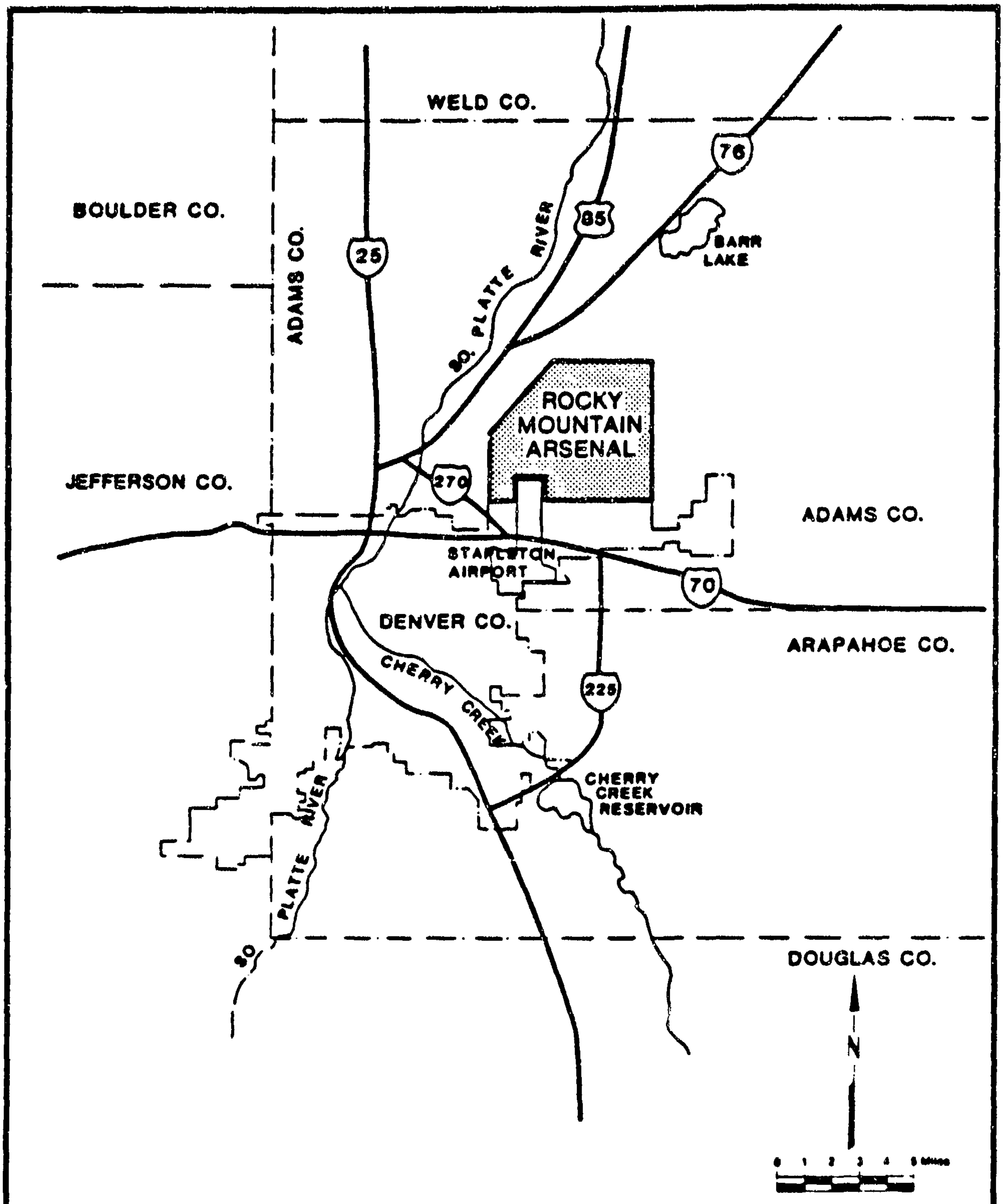

Figure 1.1-1
LOCATION MAP OF
ROCKY MOUNTAIN ARSENAL
SOURCE: ESE, 1988

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

at sites of known or suspected contamination and from onpost and offpost control areas were analyzed. Section 4.0 presents the resulting data on the types and concentrations of contaminants in biological tissues from RMA. Section 5.0 assesses the distribution and concentration of contaminants in biota and the associated abiotic environment to evaluate pathways for contaminant movement within aquatic and terrestrial ecosystems, and evaluates this information in relation to observed and possible effects. This document presents the current nature and extent of contamination in biota and is based on studies conducted in accordance with requirements for the remedial investigation of biota under current applicable legislation.

1.1 SITE BACKGROUND

RMA was established in 1942 for manufacturing chemical and incendiary munitions, and in later years was the site for demilitarization (destruction) of chemical ordnance. Throughout World War II (WWII), mustard gas, chemical intermediate munitions, toxic end products, and incendiary munitions were manufactured and assembled at RMA. From 1945 to 1950, RMA distilled stocks of Levinstein (H) mustard, demilitarized mustard-filled shells, and test-fired 107-millimeter (mm) mortar rounds filled with smoke and high explosives. Many different types of obsolete WWII ordnance were also destroyed by detonation or burning at that time. In this period and in subsequent years the production, handling, or demilitarization of sarin (GB), lewisite, arsenous chloride, chlorine gas, cyanogen chloride (CK), phosgene (CG), and incendiary bombs have occurred at RMA. Munitions filling operations ceased in 1969. Since 1970, the primary U.S. Army activity at RMA has been demilitarization of chemical warfare agents.

Industrial chemicals were manufactured at RMA by several different lease holders from 1947 to 1982 (USATHAMA, 1984). In 1947, facilities not being used by the Army in the South Plants area of RMA were leased to the Colorado Fuel and Iron Corporation (CF&I) for chemical manufacturing. CF&I manufactured chlorinated benzenes, dichlorodiphenyltrichloroethane (DDT), naphthalene, chlorine, and fused caustic. Julius Hyman and Company (Hyman) also occupied facilities in the South Plants in 1947, and produced chlordane, aldrin, and dieldrin, and conducted pilot studies on endrin at

RMA (USA CWS, 1952). CF&I's lease on the chlorine/caustic plants was terminated late in 1949. Hyman leased some of the facilities previously leased to CF&I and began producing chlorine and caustic in 1950 (Hyman, 1953). Shell Chemical Company (SCC) acquired all the corporate stock of Hyman in May 1952, assuming pesticide manufacturing operations from this company. Products manufactured by SCC included insecticides (such as Akton, Aldrin, Azodrin, Ciodrin, Dieldrin, Landrin, Nudrin, Parathion, Pydrin, Supona, and Vapona), herbicides (such as Atrazine, Bladex, and Planavin), nematocides (such as dibromochloropropane and DD soil fumigant), chlorine and caustic (until 1953), adhesives, anticers, curing agents, cutting oil additives, gear oil additives, and lubrication greases. SCC stopped their production activities in 1982. They continued to hold the lease on facilities until 1987.

Despite the industrial, military, and land management applications of the past, RMA continues to contain a variety of terrestrial and aquatic habitats. The majority of the land purchased for the establishment of RMA in 1942 had been used for agriculture. Since that time, RMA has been entirely fenced, and except for occasional grazing and agricultural permits in the 1940's, has been closed to the public. Many of the undeveloped areas in the northern and eastern portions of RMA contain gently sloped hills, with grassy slopes intermixed with disturbed vegetation types and areas replanted with crested wheatgrass. Industrial uses dominate the central sections of RMA, while the reservoirs, riparian areas, and most trees are found in the southern sections. The diversity of habitat, isolation of RMA from surrounding land use, and lack of public hunting inside its borders has led to the great diversity of wildlife, rivalling that of any site on the Front Range corridor including the existing government parks and preserves.

Aquatic and riparian habitats are well represented on RMA, although only two natural water bodies exist. The only stream crossing RMA is First Creek. The only other natural water body at RMA is North Bog, where ground water rises to the surface. Through impoundments and barriers, the bog has been made into a small pond since the establishment of RMA (Cooper et al., 1980, RIC#81336R18). The water and soils of North Bog have been contaminated in the past by seepage through the various basins into the water table, which then flows up through the North Bog.

The four reservoirs in the southern half of RMA, Lower Derby and Upper Derby Lakes, and Lakes Mary and Ladora, are known collectively as the Lower Lakes (see Figure 1.1-2). Lower Derby Lake is the largest reservoir at RMA, and can be seen in its present location in pre-Arsenal (1937) aerial photographs near the small town of Derby, as can Lake Ladora (MKE, 1987). Lower Derby and Lake Ladora were enlarged to provide cooling water for production activities in the South Plants. Upper Derby Lake was created for the same purpose soon after establishment of RMA. These three lakes became contaminated as a result of production activities at RMA. Lake Mary was formerly a swampy area just below Lake Ladora. In 1960, the surface water flowing from Ladora was blocked behind a berm (EBASCO, 1986, RIC#87216R07). Since its creation, Lake Mary has been used as a recreational area for both visitors and onpost personnel.

Areas immediately bordering RMA exhibit varied land uses. To the north and east, the land is primarily agricultural, although a great deal of business and residential activity is planned nearby with the new Denver airport site 5 miles (mi) to the east of RMA. The southern border is lined by the Denver residential community of Montbello, and the present Stapleton International Airport. Commerce City borders RMA on the west, with both residential and industrial land uses. The South Platte River is less than 2 mi from the northwest border of RMA, and its drainage is included in the study area for water resource assessments, as well as for offpost biota studies.

1.2 NATURE AND EXTENT OF THE PROBLEM

Waste disposal practices from manufacturing processes at RMA have included routine discharge of industrial waste effluents to lined and unlined evaporation basins and burial of solid wastes at various locations. Unintentional spills of raw materials, process intermediates, and end products have occurred within the manufacturing complexes at RMA. Demilitarization and training with munitions have led to further contamination of areas across RMA. Contaminants have also been unintentionally released into the Lower Lakes.

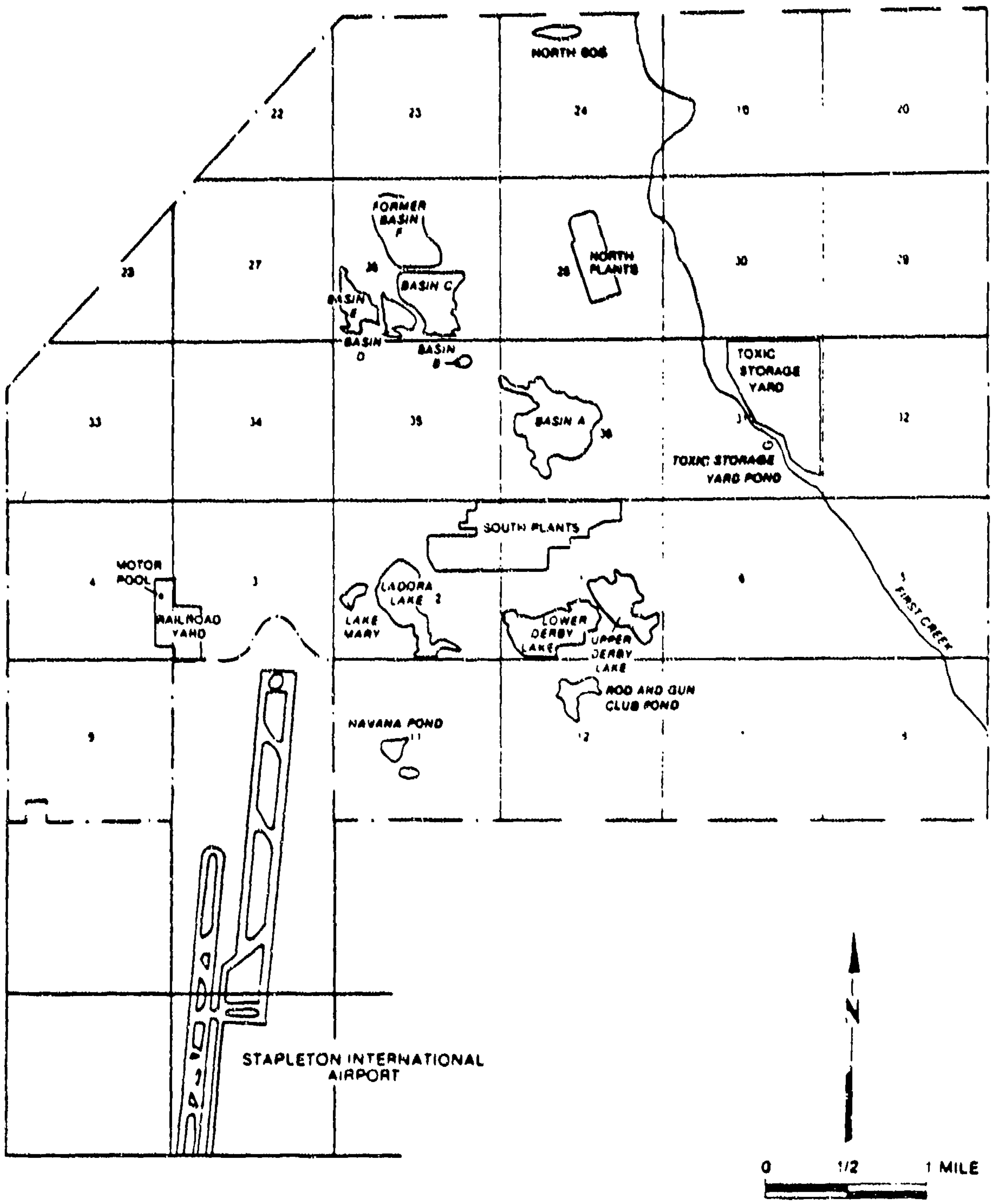

Figure 1.1-2
BASINS AND WATER BODIES ON RMA

SOURCE: ESE, 1988

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

Some of the most important sources for contamination of biota on RMA are the waste water basins located in Sections 26, 35, and 36 (Figure 1.1-2). Waste water basins used at RMA caused appreciable damage to wildlife. The Lower Lakes are also sites of past contamination and wildlife damage. However, the sites mentioned above were not the only possible locations of contamination. The problem of contaminated ground water at RMA has been recognized since the mid-1950's when ground water in wells just off RMA that were used for irrigation resulted in crop damage and potential exposure to wildlife. The Army produced Tx, an anit-crop agent (wheat rust spores) non-hazardous to wildlife or human, on about 600 acres of wheat fields on RMA from 1962 to 1968. Within Section 36, there is historical evidence of pesticide pits, munitions testing areas, burn sites, settling ponds, and trenches. Parts of Sections 3, 4, 5, 6, 11, 12, 19, 20, 27, 29, 30, 31, 32, and 35 of RMA contain some or all of the following: munitions impact areas, burn sites, disposal pits, spill areas, and burial trenches. Contaminants in these areas may include volatiles, pesticides, herbicides, inorganics salts, Army chemical agents and their degradation products, and heavy metals.

' complete history and assessment of contaminant levels and sources in the RMA environment may be found in the Contamination Assessment Reports (CARs) and the Remedial Investigation (RI) documents for each study area and medium of the RMA environment. A more detailed history of contamination and waste disposal at RMA is presented in Section 4.1 of this document.

1.3 INVESTIGATION SUMMARY

Mortality to wildlife, particularly waterfowl, from contamination sources on RMA was considerable in the past. The focus of documentation of this mortality has been on the Basins and Lower Lakes. Past investigations of wildlife have centered primarily on causes of mortality of waterfowl and contaminant levels leading to injury in other wildlife. Since the late 1940's, deaths and abnormal behavior have been recorded for several waterfowl species and a variety of other birds, mammals, and fish in the Lower Lakes. Subsequent observation and testing of these animals indicated that wildlife found dead, dying, or displaying unusual behavior contained high levels of dieldrin and other organochlorine compounds. The basin areas have been sites of major wildlife mortality as well, resulting from a variety of GB agent by-products, pesticides, and heavy metals. Table 1.3-1 is a listing of wildlife injuries documented on RMA from 1949 to 1982. More recent wildlife injuries are addressed in this report. Additional data on contaminant levels in biota collected historically at RMA will be reviewed in Section 4.1.

Various studies outlining the composition and diversity of wildlife have been completed at RMA. Among those studies are baseline ecological surveys by the Army at RMA by USA (1973), Fairbanks and Kolmer (1976, RIC#84219R01), Gauthier et al. (1977, RIC#81321R01), and Thorne (1986a, RIC#86066R01). The results of ecological studies are incorporated into the description of the environment in Section 2.0.

1.4 REPORT OVERVIEW

This report includes information developed during the assessment of biota in relation to RMA contamination. The general objectives of the biota assessment were:

- To evaluate current and historical data on the sources, types, distribution, and concentrations of RMA contaminants in biota;
- To provide specific information on the migration and accumulation of contaminants through regional food webs in relation to important species and to overall ecosystem effects; and
- To assess the environmental effects of RMA contamination.

Data were obtained on the current distribution and concentration of contamination in RMA biota and were evaluated in relation to chemical contamination in the abiotic environment and to control sites outside the defined RMA study area. Pathway analysis was used to examine relationships between the abiotic and biotic environment and among components of the biota (e.g., food webs). Additional studies of contaminant effects were conducted in conjunction with contaminant distribution studies in order to determine the relationships between observed adverse effects (e.g., reductions in reproductive success) and RMA contamination.

Table 1.3-1. Wildlife Injury Incidents, Miscellaneous or Unknown Locations (1949 to 1982) (Page 1 of 3)

Date	Species	Location	Injury Category	Notes	Reference
1949-1959	Ducks	Lower Lakes	Death (20,000 minimum)	Unknown Causes	Finley, 1959
1952	Ducks	Lower Lakes	Behavior Abnormality and Death (Test vs Control Areas As Well)	Unknown Causes	McEwen, 1981 USFWS, 1982b
1955	Duck	Lower Lakes	Death	High level of dieldrin in tissues	McEwen, 1981 USFWS, 1981
1959-1960	Leopard Frog Chorus Frog (Tadpoles)	Lower Lakes	Dead	Aldrin, dieldrin, in water, mud, snails, algae	McEwen, 1981
01/28/62	Ducks	Lower Lakes	Death (>160)	High dieldrin levels in tissues caused death	McEwen, 1981
01/66-05/66	Waterfowl	Lower Lakes	Death (163)	High dieldrin levels in in tissues caused death	USFWS, 1985
04/73	Ducks	Basin C	Death (136)	Dieldrin in mud, water, tissue	USA DPG, 1973
04/73-05/73	Ducks	Basin F	Death (Large Numbers)	Aldrin, dieldrin in tissue	USA DPG, 1973
05/73	Toads	Basin D	Death, Physical Deformity	Dieldrin in tissue	USA DPG, 1973 USA DPG, 1973
05/16/73	Largemouth Bass Bluegill Catfish	Lower Lakes	Fish Kill/Death	Aldrin released into lake prior to fish kill	USA DPG, 1973 USA DPG, 1973 USFWS, 1982b
1974	Ducks	Basin F	Death	"Detergents" Wet Feathers-Caused loss of body heat	USA DPG, 1975c
05/01/75-05/02/75	Grebe	Basin F	Death (291 Birds Total)		McEwen, 1981
	Coot	Basin F	Death		McEwen, 1981
	Merganser	Basin F	Death		McEwen, 1981
	Ducks	Basin F	Death		McEwen, 1981
	Buteo Hawks	Basin F	Death		McEwen, 1981
	Burrowing Owl	Basin F	Death		McEwen, 1981
	Pheasants	Basin F	Death		McEwen, 1981
	Songbirds	Basin F	Death		McEwen, 1981
	Shorebirds	Basin F	Death		McEwen, 1981
	Loon	Basin F	Death		McEwen, 1981
06/24/75	Western Grebe (2)	Basin F	Death	High aldrin, dieldrin levels	Linki & Stiles, 1976
	Ruddy Duck (1)	Basin F	Death		Linki & Stiles, 1976
	Coot (1)	Basin F	Death		Linki & Stiles, 1976

Table 1.3-1. Wildlife Injury Incidents, Miscellaneous or Unknown Causes Locations (1949 to 1982) (Continued, Page 2 of 3)

Date	Species	Location	Injury Category	Notes	Reference
06/76	Starlings	RMA Roosts	Death (>10/yr)	High dieldrin levels in tissues caused death	USA EHA, 1976
06/76	Red-tailed Hawk	RMA	Death	High dieldrin levels in tissues	USA EHA, 1976
11/03/76	Great Horned Owl	RMA	Death*	Pesticides in tissues	Thorne, 1984
12/08/76	Coyote	RMA	Death*	Pesticides in tissues	Thorne, 1984
03/07/77	Starling	RMA Roosts	Death*	Pesticides in tissues	Thorne, 1984
03/18/77	Ferruginous Hawk	RMA	Death*	Pesticides in tissues	Thorne, 1984
04/12/77	Starling	RMA Roosts	Death*	Pesticides in tissues	Thorne, 1984
04/18/77	Rainbow Trout	Lower Lakes	Death*	Pesticides in tissues	Thorne, 1984
12/08/77	Ferruginous Hawk	RMA	Death*	Pesticides in tissues	Thorne, 1984
04/05/78	Marsh Hawk	RMA	Death*	Pesticides in tissues	Thorne, 1984
01/29/79	Ferruginous Hawk	RMA	Death*	Pesticides in tissues	Thorne, 1984
02/27/79	Rough-legged Hawk	RMA	Death*	Significant concentrations of CPM sulfone in tissue	Thorne, 1984
06/80	Migratory Birds	Basin F	Death (375)		Anderson, 1981
10/80-12/80	Waterfowl	Basin F	Death (49)		Anderson, 1981
03/30/81	Canada Goose	Lower Lakes	Death*	Pesticides in tissues	Thorne, 1984
Fall 1981	Mallard (1)	Lower Lakes	Behavior Abnormality and Death	Dieldrin, DDE, endrin, PCB	McEwen, 1983
03/01/82	Red-tailed Hawk	Section 6	Death		USFWS, 1983
03/29/82	Red-tailed Hawk	Section 36	Death	Dieldrin, endrin, DDE, heptachlor epoxide, polychlorinated biphenyls in tissues	USFWS, 1983
04/06/82	Gadwall	Basin F	Death		USFWS, 1983
05/05/82	Eared Grebe	Lower Lakes	Found Dead*		USFWS, 1983

Table 1.3-1. Wildlife Injury Incidents, Miscellaneous or Unknown Locations (1949 to 1982) (Continued, Page 3 of 3)

Date	Species	Location	Injury Category	Notes	Reference
05/14/82	Magpie	Lower Lakes	Found Dead*		USFWS, 1983
05/14/82	Starling	Building 111	Death*		USFWS, 1983
05/25/82	Northern Oriole	Building 111	Death*		USFWS, 1983
05/25/82	Brewer's Blackbird	Building 111	Death*		USFWS, 1983
06/09/82	Great Blue Heron	Lower Lakes	Found Dead	Dieldrin, endrin, DDE, heptachlor epoxide, polychlorinated biphenyls in tissues	McEwen and DeWeese, 1985
06/09/82	Muskrat	Lower Lakes	Found Dead*		USFWS, 1983
06/23/82	Pheasant	North Bog	Death*		USFWS, 1983
1982	Kestrel	RMA Kestrel boxes		Dieldrin and DDE in eggs, juveniles	DeWeese et al., 1982a DeWeese et al., 1982b DeWeese et al., 1982c

* Concentrations of pesticides were found in animal.

Source: ESE, 1988 and as noted in reference column.

Studies were conducted in conformance with guidance provided in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR Part 300 (EPA, 1985j) and the Guidance on Remedial Investigations under CERCLA (EPA, 1985i). The requirements for scoping the investigation, conducting the site assessment, and evaluating results were followed, as appropriate, in conducting the remedial investigation of biota in a manner consistent with current hazardous waste site cleanup legislation and site-specific requirements.

RMA contamination in biota has been documented since the 1950's. This information on past history of contamination and contamination studies for biota is summarized in this document, which focuses on current biota contamination and its ecological effects. Information on contaminant concentrations in tissue (e.g., cottontail rabbit muscle) will also be used in the offpost endangerment assessment that examines and quantifies the wildlife pathway of human exposure and addresses the extent of environmental exposure.

Criteria developed as a result of biota pathways analyses can also be used as a guide to site remediation and to determine the spatial distribution of contamination above levels that adversely impact wildlife in abiotic media. These criteria may also be selected as remedial action levels, if appropriate. Quantitative evaluations of the location and distribution in these media (e.g., soil) will be evaluated in conjunction with other considerations and incorporated into each of the appropriate Study Area Reports (SARs) as the Phase II data on contaminant distribution in these media become available.

2.0 ENVIRONMENTAL SETTING

RMA occupies an area of low, rolling terrain characterized by grasslands, shrublands, wetlands, aquatic habitats, and extensive weedy areas supporting a variety of plant and wildlife species. The South Platte River flows parallel to the northwest boundary and approaches to within 2 mi of RMA (Figure 1.1-1). The area surrounding RMA is largely ranch/farmland, rural and urban residential, and industrial (Kolmer and Anderson, 1977, RIC#81295R07).

Land north and east of RMA consists mostly of rangeland (grassland) and land used for dryland agriculture. Rural residential developments are scattered north and northwest of RMA. Urban developments and associated industrial complexes include Commerce City (west) and Montbello (south). The north runways of Denver's Stapleton International Airport extend into the southwestern corner of RMA.

Cropland and range habitat north and east of RMA provide habitat for a diversity of wildlife, including game species such as cottontails, ring-necked pheasants, and mourning doves. Lake and wetland areas at Barr Lake State Park (Barr Lake), 5 mi to the northeast and downstream from RMA support a variety of wildlife species and provide staging, breeding, and resting areas for waterfowl; habitat for edible fish species; and winter habitat for the bald eagle, an endangered species.

2.1 PHYSICAL ENVIRONMENT

2.1.1 PHYSIOGRAPHY AND SURFACE WATER

The topography in the vicinity of RMA consists of stream-valley lowlands separated by gently rolling uplands. The maximum local topographic relief in the area is about 200 feet (ft); the elevation above mean sea level (msl) ranges from about 5,330 ft at the southeastern boundary of RMA to about 5,130 ft at the northwestern boundary of RMA. The average elevation across RMA is 5,250 ft msl.

The South Platte River originates in the Rocky Mountains southwest of Denver, and then flows in a general north-northeast direction before swinging to the east in the vicinity of Greeley, Colorado. The overall surface drainage in the region is toward the northeast and into the South Platte River. Natural tributaries flowing from RMA to the South Platte River drain to the northwest. All of RMA is drained by the South Platte River and its tributaries (Figure 2.1-1). However, two major irrigation canals, O'Brian Canal and Burlington Ditch, and several smaller ditches run southwest to northeast between RMA and the South Platte River. O'Brian Canal and Burlington Ditch receive drainage from RMA by interception of First and Second Creeks. These flows are either stored in Barr Lake reservoir or distributed into one or more of the many irrigation ditches downstream, depending on the season and the quantity of water available.

The several manmade lakes and ponds on RMA, as well as several basins were created for industrial cooling or the storage and disposal of chemical and industrial waste (Figure 2.1-1). The Lower Lakes are supplied with water from the Highline Lateral. Small ponds on RMA include Gun Club Pond, Havana Ponds, Toxic Storage Yard Pond, and the North Bog. A more detailed account of the physiography and the surface water of RMA is provided in the Water Remedial Investigation Report (EBASCO, 1989).

2.1.2 CLIMATE

RMA is located at the western edge of the plains of Colorado and near the foothills of the Rocky Mountains. The area is generally classified as mid-latitude and semi-arid. Climate data were collected at Stapleton International Airport, which is adjacent to RMA. Because of the close proximity and relatively uniform topography between Stapelton International Airport and RMA, the climatological and meterological conditions are expected to be the same between the two sites.

The climate of this area is characterized by low relative humidity, abundant sunshine, relatively low rainfall, moderate to high wind movement, and a large daily change in temperature. The mean maximum temperatures range from 43 degrees Fahrenheit (^{O}F) in January to $88^{O}F$ in July. The mean minimum temperatures are $16^{O}F$ in January to $59^{O}F$ in July.

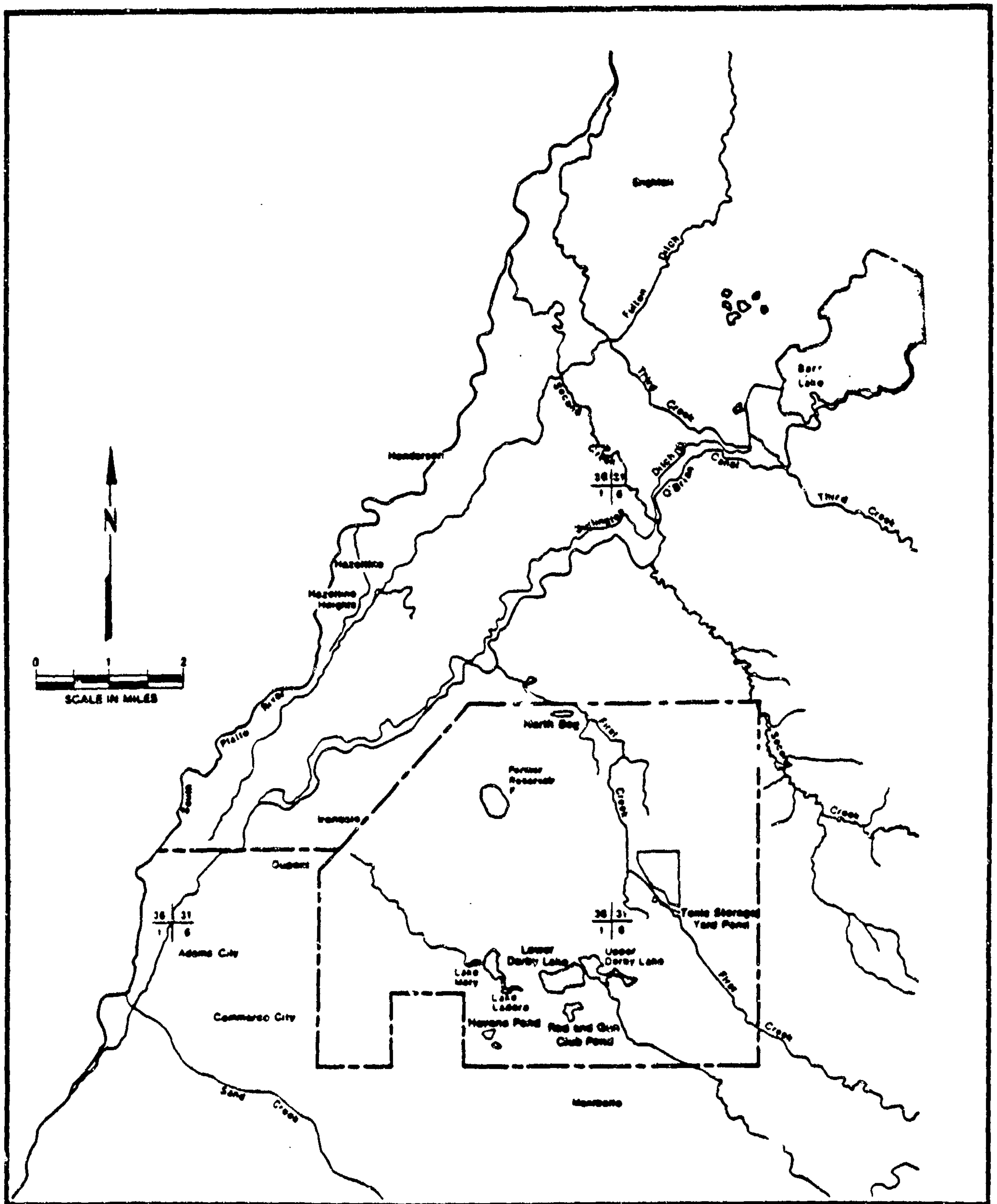

Figure 2.1-1
SURFACE WATERS ON AND NEAR RMA

SOURCE: ESE, 1988

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

Occasionally, a meterological phenomenon known as a Chinook wind descends along the eastern slope of the state during winter months. These winds bring large and sudden rises in temperature, as much as 25° to 35°F within a few hours. These winds are warm because they are decreasing in elevation and thus warming at the adiabatic rate (5.5°/1,000 ft). Chinook winds greatly moderate winter temperatures in RMA vicinity.

As a result of Colorado's distance from major sources of moisture, such as the Pacific Ocean and the Gulf of Mexico, and the presence of the Rocky Mou[illegible] precipitation is relatively light in lower elevations. Storms ori[illegible]g in the Pacific and moving eastward lose much of their moisture as they pass over mountain ranges in western Colorado. Precipitation in the RMA vicinity is approximately 15 inches per year. Spring is the wettest, cloudiest, and windiest season. Fifty-one percent (%) of the total annual precipitation falls between the months of April and July. Much of this moisture falls as snow during the colder, earlier period of the season. Summer precipitation comes mainly from scattered local thunderstorms during the afternoons and evenings, particularly in July and August. In autumn, there is less cloudiness and a greater percentage of sunshine than at any other time of the year: precipitation amounts to about 19% o[illegible] the annual total. Winter has the least precipitation accumulation, (approximately 13% of the annual total) and almost all of it is snow. There are approximately 93 days per year with a cloud cover of 30% or less.

The prevailing winds at RMA are from the south and south-southwest. Wind speeds average about 9 mph annually. The windiest months are March and April, with gusts as high as 65 mph. More detailed climate data for the RMA region is provided in the Air RI report (ESE 1988a, RIC#88263R01).

2.2 REGIONAL BIOTA

Regional biota include plant and animal species that are known to occur on and in the vicinity of RMA. Because of the large expanses of diverse habitats, the same species that occur in the region also inhabit RMA. In some instances the same species occur onpost and offpost, but their habitat use is different (e.g., bald eagles occupy breeding habitat at Barr Lake throughout the year while bald eagles migrating in from other areas use RMA for up to five months for winter roosting, foraging, and daytime loafing (ESE, 1988b)]. Appendix A lists the common and scientific names of plants and animals occurring in the region, and their record of occurrence.

2.2.1 MAJOR ECOSYSTEMS

The region that includes RMA is characterized by small areas of diverse habitats (e.g., tree groves, riparian woodlands, wetlands, ponds, and surface streams) scattered throughout onpost and offpost grasslands; pastureland, cropland, and urban areas also exist offpost. From an ecological perspective these habitats can be focused into two major ecosystem types: terrestrial and aquatic. Biota inhabiting various specific habitats (e.g., ducks in wetlands, raptors in tree groves) are part of the interconnected food webs and other interactions of the two major ecosystems.

2.2.1.1 Terrestrial Ecosystems

Terrestrial ecosystems in the region are dominated by grassland, interspersed with riparian woodland, small groves of trees, and weedy herbaceous vegetation. Much of the offpost area north and east of RMA is used either as pastureland or cropland, while areas south and west of RMA are heavily urbanized.

Vegetation

RMA lies within the North Temperate Grassland biome (Shelford, 1963) which generally extends from north-central Texas into central Alberta, and from Indiana into portions of California. The specific region including RMA is referred to as the High Plains district of the Northern Great Plains province. The region is typically dominated by a mosaic of grassland communities with a diverse component of forbs ("wildflowers"). Tall-grass species tend to occur in the more mesic (moist) areas, with short-grass species in more xeric (dry) sites. Throughout the region; however, there exists considerable gradation and mixing between the two extremes.

Periodic fires and grazing by pronghorn and large herds of bison may have played a major historic role in maintaining the grassland vegetation. Most of the original vegetation has been destroyed in modern times by plowing of native sod and overgrazing by domestic livestock. Control of fire has also caused shifts in species dominance. The following description is based on the potential "climax" (i.e., long-term, self-sustaining) vegetation of the region, as portrayed by Kuchler (1964).

Climax Communities -- In Colorado, prairie grasslands occur mainly on the Great Plains east of the Rocky Mountains. Prior to settlement, dominant vegetation in the area was mid-grass prairie, interrupted by sparsely vegetated sand hills, with ribbons of riparian woodland and fragments of tall-grass prairie along stream courses.

At the western edge of the Great Plains, where the prairies give way to mountains, the grassland communities are mixed and variable, owing to diversity of topography, soils, and climate. Variations in topography and soils result in a mosaic of vegetation. Western wheatgrass dominates in areas such as shallow depressions and broad drainageways where fine soil has accumulated. Side-oats grama, prairie junegrass, little bluestem, and big bluestem occur where soil moisture is more available. In moist bottomlands, big bluestem can form pure stands. Upland areas are characterized by short-grass species, particularly blue grama. Farther east, a mixed short-grass community of blue grama and buffalo grass prevails on uplands. Soils are loamy, but runoff may be high and infiltration low so that available moisture is confined to the first 2 ft of soil during most of the growing season. Species with fibrous, shallow roots such as blue grama and buffalo grass are best adapted to these areas. Needle-and-thread, green needlegrass, sand dropseed, western wheatgrass, red three-awn, and threadleaf and needleleaf sedges are also common components of this community. Important forbs in the short-grass and mid-grass communities include prairie coneflower, dotted gayfeather, greenthread, silvery lupine, and umbrella plant. Species diversity can be high in this vegetation zone because of the variable but generally favorable substrate conditions.

On the sandy soils scattered across eastern Colorado, the prevalent species include sand sagebrush, prairie sandreed, sand bluestem, switchgrass, red three-awn, and Indian ricegrass. Important forbs include slimflower scurfpea, bush morning-glory, and yucca. Rocky ridges may support little bluestem, side-oats grama, needle-and-thread, and ring muhly.

Riparian woodlands and associated wetland areas follow the water courses out of the mountains and onto the plains. Plains cottonwood and peachleaf willow dominate the overstory, with lesser numbers of box-elder and hackberry. The understory includes shrubby willows and a variety of mid-grass and tall-grass species. Golden currant, wild rose, chokecherry, and snowberry may also occur in mesic areas; wild plum and hawthorn may form dense thickets in such sites. Cattails and bulrushes may dominate minor drainages. Western wheatgrass, inland saltgrass, and alkali sacaton are conspicuous dominants on bottomlands with finer saline soils.

Historically, the occurrence of forbs in the grasslands has varied with substrate and microclimate. Common perennial forbs in addition to those already named include scarlet globemallow, prairie aster, scarlet butterfly weed, prickly pear cactus, fringed sagewort, western wallflower, and skeleton-weed. Annual forbs include plantain, prairie peppergrass, and narrowleaf goosefoot. Six-weeks fescue, an annual grass, is also a widespread component.

The occurrence of shrubs is also variable across the plains of Colorado, and is determined primarily by substrate and topography. Rubber rabbitbrush and broom snakeweed probably have the widest distributions.

Successional Processes -- Shantz (1911) developed a method of evaluating agricultural potential based on existing native vegetation. This system designated the blue grama-buffalo grass areas as the most productive under cultivation, when water was sufficient. Areas of deep sand, as indicated by sand sagebrush, were designated as the least productive and most susceptible to wind erosion. Today in eastern Colorado, remnant native vegetation is generally located on sandy soils, which are less arable. Most of the short-grass area has been in continuous cultivation for decades, or was cultivated but then abandoned and covered by successional species. Even the remnant unplowed areas have generally been altered by prolonged grazing of cattle, and thus have been held in a disturbed or "disclimax" state. Since most of the original vegetation in the region has been disturbed in one way or another, a general description of successional processes for the area may provide a more realistic view of uncultivated regional vegetation than the discussion of climax communities.

Successional development on disturbed areas surrounded by undisturbed vegetation (and, hence, with a nearby seed source) generally begins with colonization by annual forbs such as Russian-thistle, goosefoot, sunflower, pigweed, prostrate knotweed, and various mustards. In some seasons, perennial forbs and a few perennial grasses invade. These persist for several years, during which short-lived perennial grasses such as sand dropseed and foxtail barley become more prevalent. Ultimately, the natural transition to mixed prairie occurs as longer-lived grasses such as blue grama and buffalo grass become established and dominate (Costello, 1944). If, at any time during this process, cheatgrass invades the disturbed area, the successional process may be arrested at an early stage so that longer-lived perennial grasses are prevented from establishing and predominating. This process has occurred on disturbed areas in close proximity to cultivated or other disturbed lands throughout the RMA region.

Today, some unplowed areas contain relict stands of native grassland, although such communities are rare in the vicinity of RMA. Natural restoration of native grasslands is an extremely slow process, and thus, little improvement may be evident in previously disturbed areas that have lain fallow for many years.

Wildlife

The terrestrial fauna of the region is dominated by species of prairie, steppe, and savannah communities. The diversity of wildlife near the western edge of the plains is greatly enhanced by the diverse habitats dispersed through the grasslands. These include conifers and mountain brush on mesas extending east from the foothills, wetlands and adjacent cottonwood/willow woodlands along drainages and lakes, shade trees or shelterbelts around ranches and farms, and ornamental plantings in parks and residential neighborhoods. This great diversity of habitats provides cover, food, and reproductive habitat for many wildlife species. Approximately 471 vertebrate species potentially occur on RMA (based on geographic ranges and habitat preferences) and the surrounding area (Appendix A). These include 23 reptile, 7 amphibian, 26 fish, 360 bird, and 55 mammal species. Migratory as well as resident wildlife are represented. In addition, a diversity of invertebrate species are represented.

The region supports a variety of amphibians and reptiles. Twenty-four of the 30 species of reptiles and amphibians reportedly present in the region are considered at least fairly common, while the remaining six species are considered as uncommon or of unknown abundance (CDOW, 1981). The bullsnake, western hognose snake, milk snake, and prairie rattlesnake are widespread species in upland habitats. The bullsnake may be the most abundant reptile throughout the area. Plains and common gartersnakes are common in lowland habitats. Lizards in the region include the lesser earless lizard, short-horned lizard, many-lined skink, and six-lined racerunner.

A great diversity of bird life, including shorebirds, water birds, upland gamebirds, songbirds, and raptors, are found in the region. The lakes, ponds, and associated wetlands scattered throughout the region support many species of aquatic and marsh birds that feed in both terrestrial and aquatic ecosystems. Common breeding birds include several species of waterfowl, red-winged and yellow-headed blackbirds, common yellowthroats and song sparrows. Many species of waterfowl, including large numbers of Canada geese, utilize these habitats during the winter.

Some abundant breeding birds of habitats in the prairie include the western meadowlark, lark bunting, horned lark, grasshopper sparrow, vesper sparrow, and ring-necked pheasant (CDOW, 1982b; MKE, 1988). During winter, the western meadowlark, horned lark, and ring-necked pheasant are among the dominant prairie species.

The scattered trees, thickets, and woodlands found in the region provide nesting habitat for black-billed magpies, eastern and western kingbirds, house wrens, starlings, northern orioles, common grackles, lark sparrows, loggerhead shrikes, American robins, and Northern flickers. The dark-eyed junco, European starling, black-billed magpie, pine siskin, house finch, black-capped chickadee, northern flicker, brown creeper, and white-breasted nuthatch are common wintering birds of the woodland habitat.

Raptors are a conspicuous and important component of the regional biota. Nesting raptors in the region include bald eagle, red-tailed hawk, Swainson's hawk, American kestrel, burrowing owl, and great horned owl. Rough-legged hawks are common during the winter, as are golden eagles, ferruginous hawks, red-tailed hawks, and northern harriers. The bald eagle (a federally endangered species) also winters in the region. As many as 152 bald eagles have been recorded in the central and northeast regions of Colorado during the Colorado Division of Wildlife's (CDOW) midwinter bald eagle counts (CDOW, 1988). Wintering owls include long-eared, short-eared, barn, and great horned.

The mammalian fauna of the region is varied and representative of the diverse land uses. Small mammal trapping has indicated that large densities of certain species may be present in some areas (Gauthier et al., 1977, RIC#81321R01). Among the most abundant are the deer mouse, prairie and meadow voles, and Ord's kangaroo rat. Larger, more conspicuous rodents include the black-tailed prairie dog, thirteen-lined ground squirrel, and fox squirrel. Another abundant rodent, the plains pocket gopher, is conspicuous due to the mounds of soil it produces at the surface when it excavates its underground tunnels.

Lagomorphs (rabbits and hares) are conspicuous and common in the region. Black-tailed jackrabbits are widespread, being especially common in areas with tall grass, forbs, or shrubs. White-tailed jackrabbits are also widespread, although less common. Desert cottontail rabbits are common in rangelands, while eastern cottontail rabbits are found in riparian woodlands.

Big game mammals in the region include mule deer, white-tailed deer, and pronghorn. Mule deer are abundant on RMA and around Barr Lake, often concentrating in areas of tall weedy forbs, while white-tailed deer occupy more wooded habitats, and drainage basins throughout the area. Pronghorn occur locally in wide open rangelands and agricultural fields.

The most common predatory mammals in the region are the coyote, badger, and long-tailed weasel. Red foxes, grey foxes, swift foxes, and feral domestic dogs and cats are also locally common in the region.

2.2.1.2 Aquatic Ecosystems

Prior to settlement of the region, aquatic resources were limited to the South Plate River and its tributaries, and a small number of natural ponds and lakes. Today, numerous impoundments provide the dominant aquatic resource of the Front Range Urban Corridor. These have been constructed for a variety of purposes, including use for livestock, domestic water supply, flood control, irrigation storage, and recreation. For most of the natural lakes and ponds in the region--as well as streams and artificial water bodies--the aquatic community is constrained to a significant extent by climate, management practices and water quality. The semi-arid climate, irregular distribution of runoff events, and use of water for irrigation typically result in widely fluctuating water levels. Salinity, alkalinity, hardness, turbidity, and dissolved oxygen frequently limit the ability of a water body to support a viable fishery. The following subsections briefly characterize flowing or standing bodies of water in the region surrounding RMA.

Rivers and Creeks

Streams with sufficient basin size and runoff for permanent flow generally support an aquatic community. Most large permanent streams originate in the mountains to the west, where heavier rainfall, an extensive snowpack, steep terrain, and rocky soils contribute to the volume and persistence of flow. A few have their headwaters in prairie uplands where seepage from rock outcrops and greater precipitation are sufficient to sustain flows.

Rivers and creeks originating in the mountains are cold, swift, clear, and highly oxygenated when they emerge onto the plains. They typically are also well shaded by riparian trees and have rocky substrates. Primary production in coldwater and coolwater reaches is generally limited to periphyton attached to the coarse substrate. Macroinvertebrates are dominated by crawling forms of insect larvae (e.g., caddisflies, mayflies, and stoneflies). Densities and diversities of these organisms are high; they provide an abundant prey base for fish, especially trout. Cutthroat trout are native to these waters, and three introduced species (rainbow, brown, and brook) also occur. Native nongame fish in these stretches include the longnose sucker, longnose dace, and johnny darter.

As the streams flow eastward onto the plains, they become slower and wider, the amount of shading decreases, sediments become finer, and turbidity increases. Consequently, temperatures rise and oxygen levels fall. Primary producers in these stretches shift from periphyton to phytoplankton and macrophytes. Macroinvertebrate communities also change, being dominated by burrowing forms (e.g., dipteran larvae and oligochaete worms) and free-swimming aquatic insects (e.g., water striders, water boatmen, and diving beetles). Invertebrate diversities and densities are notably lower than in the upper stream reaches. Vertebrate aquatic species potentially occurring in the region include 26 fish and 7 amphibians. The ichthyofauna of these reaches is composed of warmwater species. Native fishes of eastern Colorado streams include the green sunfish, plains topminnow, plains killifish, fathead minnow, common shiner, and red shiner. Channel catfish are native in larger rivers especially farther east in the state and have also been widely stocked.

Amphibians present in the region include northern leopard frogs and bullfrogs in permanent water bodies, and plains spadefoot toads, Woodhouses's toads, great plains toads, and chorus frogs in a wide range of wetland habitats and temporary ponds. Tiger salamanders are found in both permanent and temporary water bodies.

Lakes and Ponds

Regional lakes and ponds generally support a warmwater aquatic community. Primary production is mostly provided by phytoplankton and macrophytes. Zooplankton, particularly copepods and cladocerans (water fleas), are an important component of standing water. Macroinvertebrates include many of Dragonflies and damselflies are important components of regional aquatic habitats, as are snails and freshwater mussels.

Fishes native to ponds and lakes in the region include the black bullhead, green sunfish, orange-spotted sunfish, and fathead minnow. Most natural or artificial ponds or small lakes of sufficient size, habitat quality, and accessability have been stocked with gamefish for recreational use. Species stocked are varied but frequently include panfish such as bluegill or pumpkinseed sunfish and predators such as largemouth bass or northern pike. Green sunfish, black bullhead, and channel catfish are also commonly stocked. Larger ponds and lakes may be stocked with walleye, yellow perch, and black crappie as well. Trout, especially rainbows and browns, are frequently added for a put-and-take fishery. Carp are ubiquitous.

Lakes and ponds may support native populations of northern leopard frogs and introduced bullfrogs. Marshy areas along pond margins may be used for breeding by northern chorus frogs, Woodhouse's toads, and great plains toads. Another anuran, the plains spadefoot, is sometimes found along small, shallow ponds. Tiger salamanders also breed in these waters. Aquatic turtles are a minor group in the region; only the western painted turtle is likely to be encountered.

2.2.2 RELATIONSHIP TO REGIONAL LAND USES

The area around RMA is subject to a variety of land uses that affect plant and animal abundance, distribution, and diversity both on and off RMA (Figure 2.2-1). Areas to the east of RMA are presently devoted to dryland farming of small grain crops (wheat, barley), vegetables, corn, and alfalfa. Species diversity and abundance tend to be greatly reduced where intensive agriculture is the dominant land use. Modern agricultural practices in the region have eliminated fence rows and wind breaks that provide food and cover for small mammals and birds. The control of "pest" species, most notably prairie dogs, has reduced or eliminated certain species from local areas. Rodent and insect control programs not only eliminate the pest species but also reduce the amount of food available to predators.

Agricultural land to the north of RMA is used for dryland crops, irrigated crops, and grazing. Here again, intensive agricultural practices have tended to reduce the diversity and abundance of vegetation and wildlife in these areas. Areas that are overgrazed tend to encourage prairie dogs to

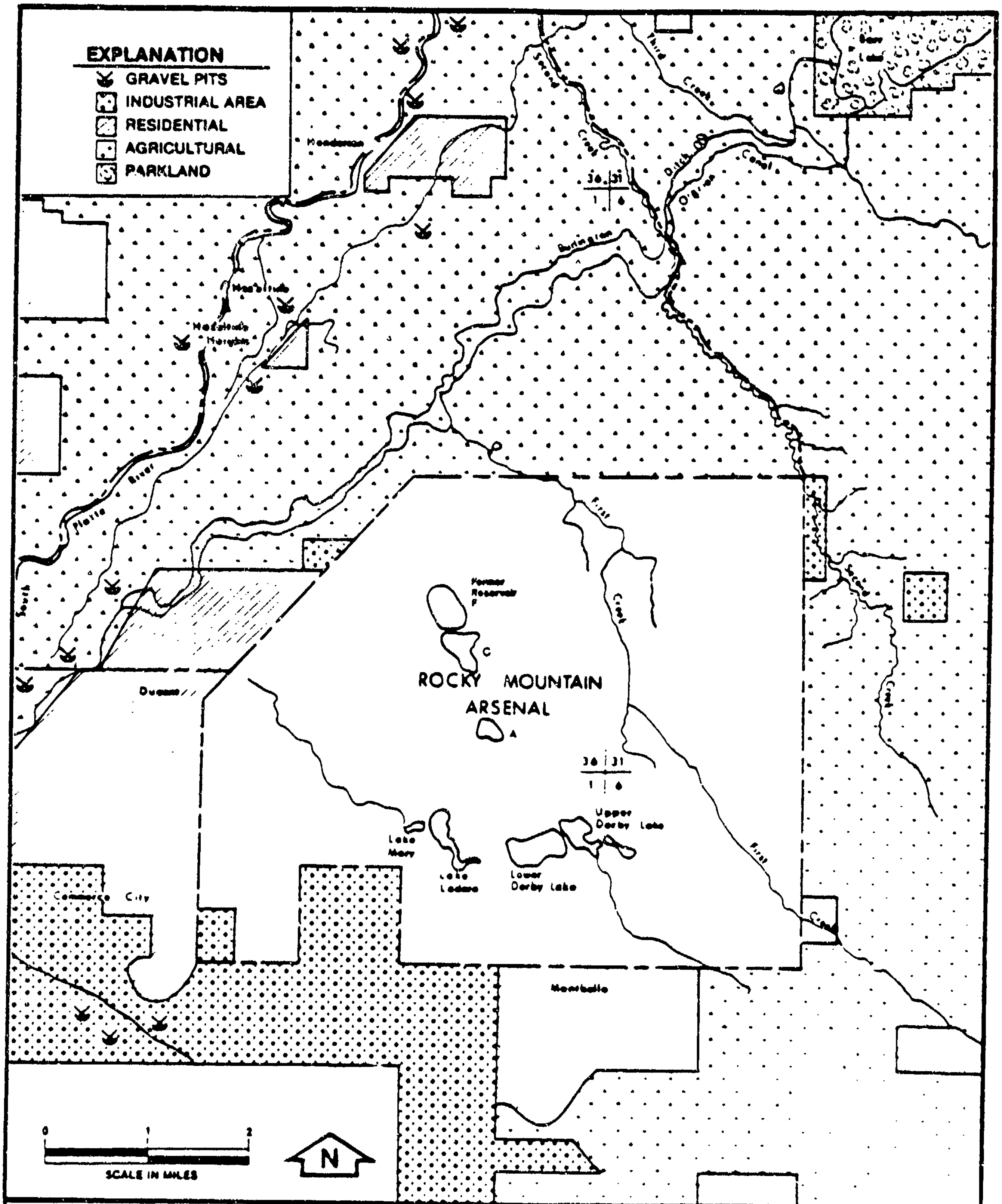

Figure 2.2-1
RMA AND SURROUNDING LAND USES

SOURCE: ESE, 1988

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

either colonize those areas, or expand existing towns. Feedlots, which attract large numbers of red-winged blackbirds and other grain-eating birds, are common in the area. When prairie dogs or bird populations reach pest proportions, control programs are initiated to eliminate or severely reduce the populations. Large acreages of sod farms north of RMA are virtually devoid of wildlife.

Urban/industrial development in Montbello and Commerce City has eliminated much of the native vegetation and simultaneously reduced the indigenous prairie wildlife species. This same urban development has subsequently provided habitat for a variety of species adapted to a metropolitan setting. Ornamental trees provide nesting areas for house finches, house sparrows, starlings, and mourning doves. Bridges and commercial buildings provide roosting areas for rock doves. Shade trees in residential areas, parks, and cemeteries provide wooded areas for fox squirrels and eastern cottontails.

Large stretches of the South Platte River from Sand Creek to the city of Brighton are currently being used for an assortment of industrial uses. Gravel excavation has consumed areas of once pristine riparian habitat. Sewage treatment plants and oil refineries have also depleted areas of wildlife habitat along the river.

Hunting of large mammals, small mammals, waterfowl, and upland game birds is a common occurrence in rural areas surrounding RMA. This activity further limits animal populations that are already limited by intensive agriculture. Other species are indirectly affected by hunting. Raptors and other predators rely on smaller birds and mammals for food: any decrease in the prey base caused by hunting may decrease the ability of the land to support predators. Raptors are also frequently shot, irrespective of federal laws that prohibit the killing of birds of prey.

Stapleton International Airport, including past expansion into Section 10 and ongoing expansion into Section 9 of RMA, maintains large open areas of grasses and weedy forbs. These areas support populations of cottontails, jackrabbits and prairie dogs, and subsequently the raptors and mammalian predators that feed on them. Other species such as deer may avoid areas of noise and disturbance and are thus generally absent from the airport.

In contrast to these surrounding land uses, RMA provides a combination of large acreages of diverse open habitats interspersed with lakes, small wetland areas and wooded areas, a mixture of native grasses and tall weedy forbs, and a lack of hunting pressure and disturbance that has contributed to an abundance of many wildlife species. Many of the species are more abundant than in similar areas off RMA. The abundance and availability of prey species attracts avian and mammalian predators.

2.3 STUDY AREA

The study area used for these investigations included all of the RMA and also the PMO-RMA study area for the Offpost Contamination Assessment, which includes Barr Lake and the upstream surface waters associated with it (Figure 2.3-1). The offpost area has been defined on the basis of the distribution of potentially contaminated ground water, surface water, and sediments that may provide sources of contamination for plant and animal species offpost.

2.3.1 TERRESTRIAL ECOSYSTEMS

Terrestrial ecosystems on RMA are typical of the eastern plains of Colorado, but land disturbances, habitat alterations, and management practices have led to an increase in habitat diversity and a greater abundance of certain species.

2.3.1.1 Vegetation

Vegetation at RMA is dominated by five broad community types: weedy forbs, cheatgrass/weedy forbs, cheatgrass/perennial grassland, native perennial grassland, and crested wheatgrass (Figure 2.3-2). These are open habitats, with only scattered trees and shrubs. Minor community types occur in areas having specific substrate or moisture conditions. Although comprising a small part of the total vegetation at RMA, these minor communities are important ecologically because of the diverse plant and animal species they support. Minor types at RMA include sand sagebrush shrubland, rubber

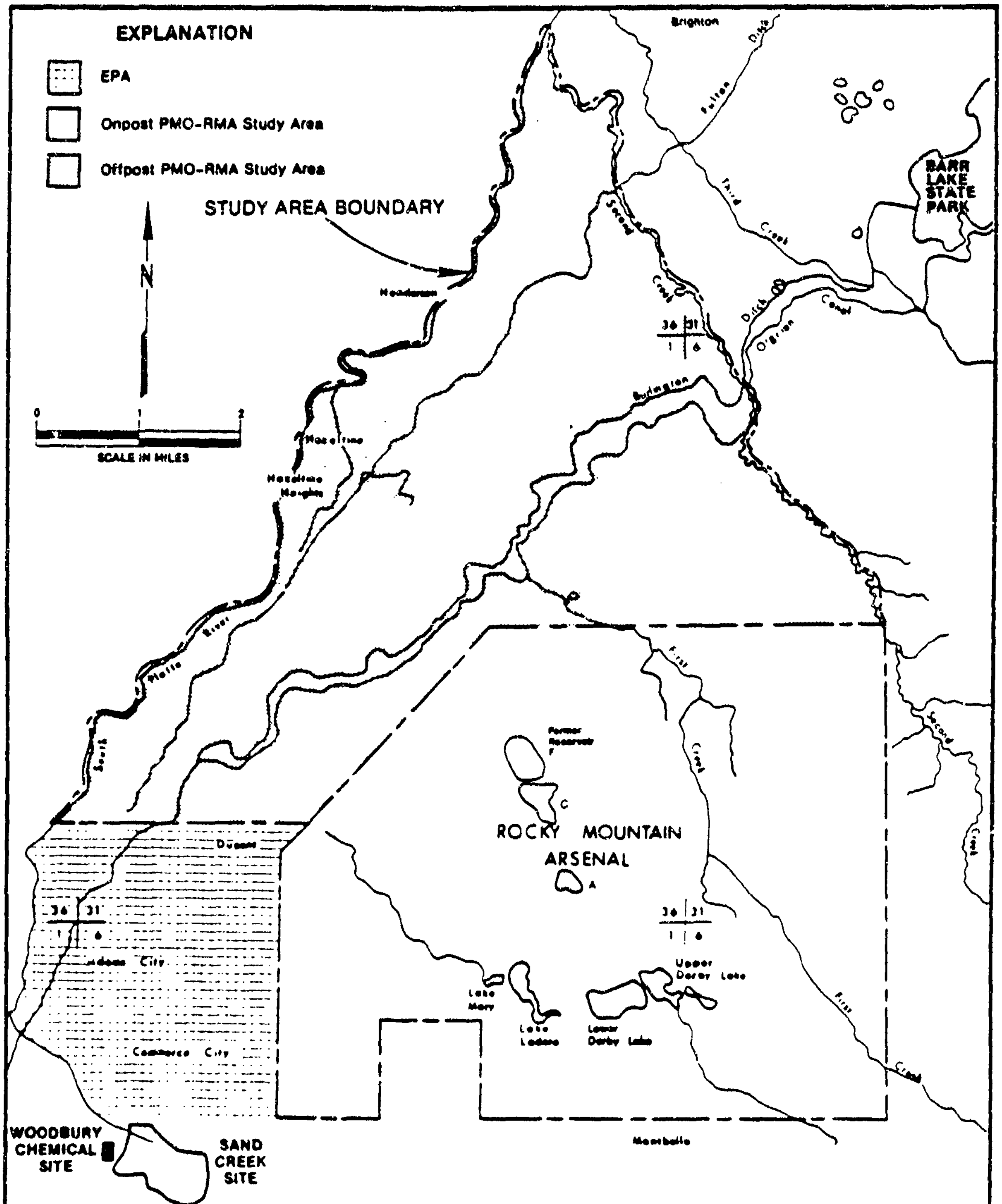

Figure 2.3-1
STUDY AREA BOUNDARIES

SOURCE. ESE, 1987

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Aberdeen Proving Ground, Maryland

Figure 2.3-2
VEGETATION MAP OF ROCKY MOUNTAIN ARSENAL
SOURCE: MKE, 1988

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal

Aberdeen Proving Ground, Maryland

rabbitbrush shrubland, yucca grassland, cottonwood/willow stands, bottomland meadows, cattail marshes, and ornamental trees and shrubs. The vegetation on RMA was described in detail to provide a basis for evaluating contamination in the flora and the habitat it provides. The resulting detailed description of the vegetation on RMA is provided in Section 3.3.1.

2.3.1.2 Wildlife

The wildlife component of RMA and the control areas contains all the major common species and most of the less common species of the regional fauna. For many species, populations at RMA are greater than in similar habitats offsite, while some species are not as abundant. In most cases, animal abundance at RMA appears to be related primarily to good habitat quality, low levels of human disturbance, and the absence of hunting and livestock grazing. The following subsections briefly describe existing wildlife resources in the study area. Common and scientific names are provided in Appendix A.

Reptiles and Amphibians

The most conspicuous reptiles at RMA are bullsnakes, which are frequently observed sunning themselves along roadways. Other snakes regularly encountered are the western hognose snake in sandy terrain, the common gartersnake and plains gartersnake near water, and the yellow-bellied racer and plains rattlesnake in a variety of habitats.

Three lizard species are known to inhabit RMA: the lesser earless lizard, short-horned lizard, and the many-lined skink. No turtles have been reported on RMA.

Probably the most abundant amphibian on RMA is the northern chorus frog. This frog species breeds in large numbers in most cattail stands and intermittent wet areas (such as Upper Derby Lake). Two frog species, the northern leopard frog and the bullfrog, are observed regularly in Lake Mary and Lake Ladora. The leopard frog is apparently more abundant than the bullfrog, and it was also observed in other wet areas, including the North Bog.

Woodhouses's toads, great plains toads, and plains spadefoot toads are occasionally found as roadkills near the Lower Lakes. All three of these species are heard calling from minor water bodies or intermittent wet areas on RMA. Upper Derby Lake supports the largest population of chorusing amphibians. Tiger salamanders are also observed on RMA, notably in the North Bog.

Water Birds

Waterfowl are a conspicuous feature at RMA. Canada geese are one of the more abundant species observed. This species has become a common resident along the Front Range in recent years and successfully breeds on RMA. Dabbling (surface-feeding) ducks observed at RMA include the mallard, northern pintail, gadwall, American wigeon, northern shoveler, blue-winged teal, cinnamon teal, and green-winged teal. All of these species are common on small ponds and lakes in the region. Dabbling ducks known to have nested at RMA during 1986 and 1987 were mallard, gadwall, blue-winged teal, and green-winged teal.

Diving ducks observed commonly on RMA include the canvasback, redhead, ring-necked duck, lesser scaup, common goldeneye, and bufflehead. Of these, only the redhead was documented to breed on the RMA. Diving ducks, unlike dabbling ducks, typically occur on large waterbodies. Lake Ladora (25 ha) received the greatest use by migrating diving ducks. Lower Derby Lake (38 ha) was less heavily used, probably because of its generally shallower depth. Additional diving ducks include the common and hooded mergansers and the ruddy duck, all of which were uncommon migrants. American coots and pied-billed grebes nested onsite and are among the most common species. Western and eared grebes are present, primarily during the migration seasons. Coots and grebes are ecologically similar to diving ducks.

Wading birds observed at RMA are the great blue heron and black-crowned night-heron. Great blue herons do not nest onpost, but feed regularly in the shallows of the Lower Lakes, Havana Pond, and marshy areas along First Creek. Black-crowned night-herons are less frequently observed, but may nest on RMA. The closest known rookery for both these species is at Barr Lake.

Gulls and shorebirds observed at RMA are typical for the region. The most commonly observed species are herring and ring-billed gulls, killdeer, American avocets, willets, greater and lesser yellowlegs, long-billed dowitchers, and spotted sandpipers. Wilson's phalaropes, white-faced ibis, Virginia rails, and soras are also observed. Kilideer and avocets nest onpost in small numbers and the Virginia rail and the sora apparently nest along the inlet of Lake Ladora, near Gun Club Pond, and on First Creek northeast of the North Plants. Other water birds observed in summer but not known to nest at RMA include white pelicans and double-crested cormorants.

Songbirds

The prevalent breeding songbirds in open (grassland, weedy forb, and shrub steppe) habitats at RMA are the horned lark, western meadowlark, grasshopper sparrow, and to a lesser extent the lark sparrow and lark bunting. Habitat diversity is an important feature in attracting additional songbird species. Mature deciduous trees along roadsides or in small clumps are regularly used for nesting by northern flickers, eastern and western kingbirds, black-billed magpies, American robins, loggerhead shrikes, northern orioles, lesser goldfinches, and lark sparrows. Ornamental and shade trees near buildings are especially attractive to house finches, house sparrows, Brewer's blackbirds, common grackles, and starlings.

Most of the species nesting in scattered trees also nest in riparian woodlands. However, the more extensive and denser growth of trees in the riparian areas, and the more diverse understory, provide nesting habitat for a variety of additional species as well. Prominent among these are the downy woodpecker, western wood-pewee, tree swallow, black-capped chickadee, gray catbird, red-eyed vireo, warbling vireo, yellow warbler, black-headed grosbeak, and indigo bunting. The riparian woodlands also attract a large number of species (both breeding and migrant) not otherwise found onpost. These include numerous house wrens, ruby-crowned kinglets, Swainson's thrushes, brown thrashers, orange-crowned warblers, yellow-rumped warblers, Wilson's warblers, chipping sparrows, white-crowned sparrows, Lincoln's sparrows, American goldfinches, and pine siskins, plus several less common species.

Other songbirds nesting on RMA include red-winged blackbirds, yellow-headed blackbirds, common yellowthroats, and song sparrows in cattail marshes. Rock doves, Say's phoebes, and barn swallows are common around abandoned buildings. In addition to supporting the typical breeding birds of eastern Colorado, RMA supports breeding populations of several species which breed only locally or rarely on the eastern plains. The short-eared owl, tree swallow, northern mockingbird, sage thrasher, and orchard oriole, as well as other species, are in this category (CDOW, 1982b). Common winter birds are the western meadowlark, horned lark, and water pipit in open areas; the American tree sparrow, dark eyed junco, and white-crowned sparrow in brushy areas; and the black-capped chickadee, brown creeper, and white-breasted nuthatch in wooded areas. Other prominent winter species include northern shrikes, and Townsend's solitaxres, plus year round residents such as house finches, house sparrows, starlings, and magpies.

Raptors

A distinctive characteristic of RMA is the density of raptors present particularly during winter. The abundance of prey, the distribution and abundance of suitable nesting and perching habitat, and the relative lack of human disturbance contribute to high population densities of hawks and owls. Nineteen species of raptors were observed on RMA between 1985 and the end of 1988 (ESE, 1988b, RIC#88174RO3; USFWS, 1988; MKE, 1988). Previous winter surveys showed that hawk densities averaged approximately five to six individuals per square mile (Kolmer and Anderson, 1977, RIC#81295R07). Studies in 1988 (ESE, 1988b, RIC#88174RO3) confirmed high raptor densities during the winter. Rough-legged hawks, ferruginous hawks, and red-tailed hawks are common during the winter, as are golden eagles. Wintering owls include long-eared, short-eared, barn, and great horned.

Two species of high federal interest, the bald eagle (a federally endangered species) and the ferruginous hawk, are present in notably large numbers during winter months. Recent winter raptor census work (ESE, 1988b, RIC#88174RO3) indicated that the ferruginous hawk is the most abundant wintering raptor on RMA. Wintering populations of the bald eagle in the region include more than 20 bald eagles roosting on RMA during the winters of 1986-1987, 1987-1988. Studies (ESE, 1988b, RIC#88174RO3, USFWS 1989, Personnel Communication) indicated that bald eagles wintering on RMA feed primarily on prairie dogs and rabbits, many of which are stolen from hawks, mostly ferruginous hawks. Small numbers of bald eagles were seen in the winter of 1985-1986, generally around the Lower Lakes, where they hunted fish (MKE, 1987). However, systematic feeding observations during the winters of 1986-1987 and 1987-1988, found very little evidence of eagles feeding at the lakes (ESE, 1988b, RIC#88174R03). This may have been a result of the lakes being frozen more during the latter two winters, but even when the lakes were open little fishing behavior was observed.

During the summer, red-tailed and Swainson's hawks, northern harriers and American kestrels are common. Swainson's hawks and American kestrels are the dominant breeders. Great horned, long-eared, short-eared, and burrowing owls are also common breeders. Twenty-one raptor nests (not including kestrel nests) were located across RMA in 1987 (Figure 2.3-3), and it is likely that others, especially long-eared and burrowing owl nests, were missed. Less common raptor species occurring on RMA are Cooper's and sharp-skinned hawks, prairie falcons and Merlins, and occasionally turkey vultures and Osprey.

Carnivores

Coyotes are the largest and most conspicuous carnivores that inhabit RMA. The species is widespread on RMA, particularly in and near prairie dog towns. Studies conducted in October and November 1986 suggested that the relative abundance of coyotes was higher on RMA than offpost locations in eastern Colorado (MKE, 1988).

Badgers are also common at RMA and are frequently observed in prairie dog towns during night surveys. Red fox, gray fox, and swift fox were observed on RMA during biota assessment studies in 1985-1987, but abundance data were not collected. Other carnivores present on RMA include raccoon, striped skunk, and long-tailed weasel.

Deer

Both mule and white-tailed deer are common and conspicuous on RMA. Total counts made in December 1986 were 133 mule deer and 22 white-tailed deer

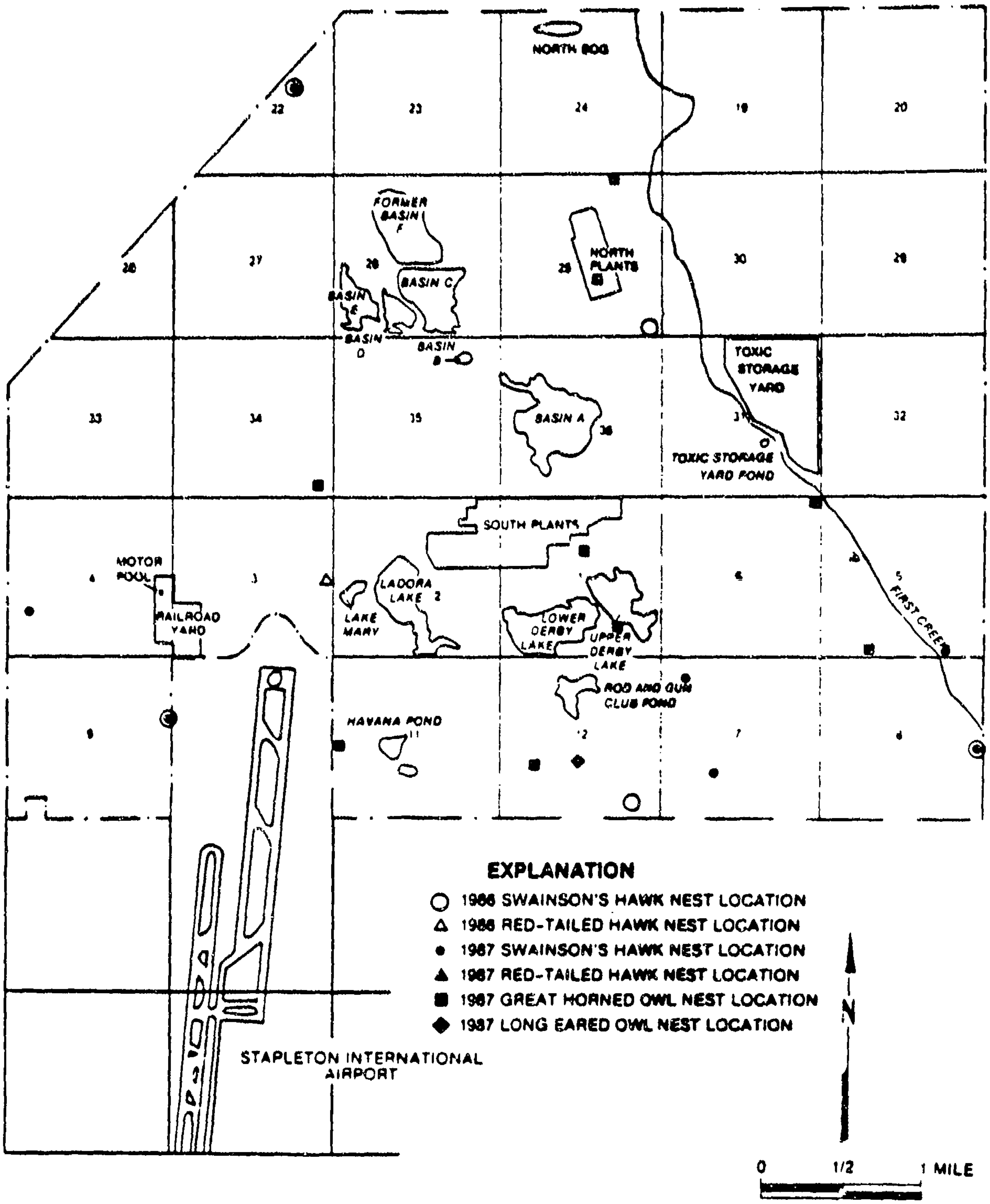

Figure 2.3-3
RAPTOR NESTS LOCATED ON RMA
IN 1986 AND 1987

SOURCE: Hunter/ESE

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Aberdeen Proving Ground, Maryland

(CDOW, 1987). Five replicate ground counts conducted by MKE on RMA in 1986-1987 revealed up to 207 mule deer (mean = 179) and 56 white-tailed deer (mean = 42). These numbers are high for the region, and both species were more abundant on RMA than at offpost comparison areas.

Cottontails and Jackrabbits

Desert cottontails and black-tailed jackrabbits are abundant across RMA. Eastern cottontails are present in thickets and riparian areas, and white-tailed jackrabbits are present in small numbers.

Prairie Dogs and Other Rodents

Black-tailed prairie dogs are the most conspicuous mammal on RMA, with extensive colonies covering approximately 5,000 acres (1,961 ha) (Clippinger, 1987). Aerial photographs and a review of the literature indicate that the colonies have expanded in recent years. Studies conducted in 1987 (ESE, 1988c, RIC#88204R01) estimated a minimum summer population density of 20 prairie dogs per ha on RMA, which is at the lower end of an expected range of 22 to 32 for the species (King, 1955, Tileston and Lechleitner, 1966). Other rodents observed at RMA include thirteen-lined and spotted ground squirrels in open habitats, fox squirrels in riparian woodlands, muskrats on all permanent bodies of water, and a variety of smaller species. Pocket gopher mounds are observed across most of RMA. Small mammals live-trapped in 1986 were the deer mouse, plains harvest mouse, western harvest mouse, northern grasshopper mouse, prairie vole, meadow vole, Ord's kangaroo rat, hispid pocket mouse, and silky pocket mouse (MKE, 1988). Tall weedy forbs, yucca, sand sagebrush, and cattails are the most productive habitats for small rodents.

2.3.2 AQUATIC ECOSYSTEMS

Aquatic habitats at RMA are largely the result of human development during the past few decades. The descriptions that follow are the results of aquatic studies conducted during 1986 through 1988 by MKE (1988) and are discussed in more detail in their forthcoming report.

2.3.2.1 Lakes and Ponds

Bodies of standing water at RMA include four impoundments collectively known as the Lower Lakes and several smaller ponds (Rod and Gun Club, Havana or South Gate, Toxic Storage Yard, and North Bog). The following subsections briefly describe the lakes and ponds at RMA. Greater detail is provided for Lakes Mary, Ladora, and Lower Derby in Section 3.3.2, because they are the only large permanent water bodies on the Arsenal and thus are of greater ecological and recreational importance overall.

Upper Derby Lake

This lake, the easternmost of the Lower Lakes, was built by the Army shortly after RMA was established in order to increase the effectiveness of the lake system for process cooling water. It is currently used only for flood and overflow storage and thus is dry most of the year. If the lake were full, it would have a surface area of about 34 ha and an average depth of less than 2 meters (m). The broad, shallow nature of Upper Derby Lake, the fact that it generally holds water only during the spring, and the presence of rooted vegetation across most of the substrate make it suitable for breeding by certain amphibians. Springtime vocalization surveys documented reproduction in Upper Derby Lake by northern chorus frogs, plains spadefoot toads, Woodhouse's toads, and great plains toads. All but the last species were present in large numbers.

Lower Derby Lake

This is the largest impoundment at RMA, with a surface area of about 38 ha and an average depth of 2 to 3 m. Lower Derby Lake receives inflow from the Irondale Gulch basin (including Upper Derby Lake) and two ditches (Uvalda Interceptor and Highline Lateral), as well as runoff from the South Plants area. Lower Derby existed as an irrigation reservoir prior to establishment of RMA, although it was enlarged by the Army and used for process cooling water.

Lake Ladora

This is the second largest lake at RMA, with a surface area of about 25 ha. The average depth is probably less than 2 m because of extensive shallows, but the deepest areas in open water exceed 5 m. Lake Ladora is located immediately below (west of) Lower Derby Lake, and like Lower Derby, Ladora pre-dated RMA but was enlarged by the Army for process cooling water.

Lake Mary

This lake is much smaller than Ladora or Lower Derby, with a surface area of only 3.2 ha. Average depth is about 2.7 m. Although it is located immediately below Lake Ladora, Lake Mary was not part of the process cooling water system. Rather, Lake Mary was constructed in 1960 as a recreational area.

Rod and Gun Club Pond

This is actually two separate ponds that coalesce during periods of peak runoff. The ponds are located just south of Lower Derby Lake in a natural depression that apparently was deepened by excavation between 1965 and 1971. Although an overflow ditch can carry water to it from Lower Derby Lake, Rod and Gun Club Pond receives runoff primarily from the surrounding terrain. There is no drainage outlet. The depression covers an area of just under 8 ha, but the pond itself covers only 2 ha and is less than 1 m deep. Electrofishing and seining in 1987 failed to produce fish, but the pond was documented to support breeding by northern chorus frogs and Woodhouse's toads. Additionally, Rod and Gun Club Pond was an important breeding area for waterfowl during the summer of 1984. Ruddy duck, American coot, mallard, and blue-winged teal were observed either displaying breeding behavior or with eggs or young (USFWS, Personal Communication, 1989).

Havana Pond

Also called South Gate Pond, this small impoundment retains runoff from residential, commercial, and industrial areas south of RMA. Most of the water is carried into the pond by the Havana Street Interceptor and Peoria Ditch, although sheet runoff from adjacent areas probably contributes some additional water. Aquatic sampling was conducted at Havana Pond in 1987. No fish were captured, but it supported large breeding populations of northern chorus frogs and Woodhouse's toads in spring. Observations conducted in spring 1984 (USFWS, Personal Communication, 1989) revealed abundant numbers of waterfowl during migration.

Toxic Storage Yard Pond

This is actually a series of three small ponds along First Creek. The ponds were formed by constructing earthen dams in an area that was previously a marshy depression. The dams have been breached, and only one small pond covering less than 0.2 ha remains. Toxic Storage Yard Pond was not sampled during field studies, but it presumably supports the same species as First Creek (plains killifish, fathead minnow, green sunfish). Toxic Storage Yard Pond currently is used for breeding by northern leopard frogs, northern chorus frogs, Woodhouse's toads, and great plains toads.

North Bog Pond

Located near the northern boundary of RMA just west of First Creek, North Bog Pond covers approximately 0.8 ha. Before RMA was built, the area was a small cattail marsh fed by a seep. The seep is now greatly augmented by excess water from the north boundary containment/treatment system. A qualitative sampling effort in May 1987 resulted in the capture of several large carp and numerous fathead minnows. The pond also supports breeding by bullfrogs and northern leopard frogs, with northern chorus frogs and Woodhouse's toads in adjacent cattail areas.

2.3.2.2 Streams

Surface runoff on RMA flows generally northwestward toward the South Platte River, which roughly parallels the northwestern boundary of RMA at a distance of about 3.2 km. Natural and artificial drainage channels on RMA are described below.

First Creek

This is the largest and ecologically most important surface drainage on RMA It drains most of the eastern half of the site (about 24 km^2) and has a total onsite length of 9.4 km. First Creek has a maximum discharge capacity of 7 cubic meters per second (m^3/sec) where it enters the southeastern corner of the RMA in Section 8, and 8.5 m^3/sec as it exits at the northern perimeter in Section 24 (COE, 1983). Its average gradient across the site is 4.9 m/km. In dry years, the flow of First Creek on RMA is continuous only during the spring and following major storms, but it generally may be characterized as a fairly persistent intermittent stream. The persistence of flow is evidenced by well-developed hydrophytic and phreatophytic vegetation along much of its length.

Several canals and ditches onpost contribute surface water to First Creek. It also receives effluent from the sewage treatment plant and overflow water from Upper Derby Lake. First Creek does not flow directly into the South Platte River, but instead is intercepted by O'Brian Canal and Burlington Ditch and thence fed into Barr Lake north of RMA.

Qualitative sampling in First Creek revealed populations of plains killifish and fathead minnows, as well as a few small green sunfish. The irregular flows and generally poor perifluvial habitat that currently characterize most of First Creek undoubtedly limit its value as an aquatic resource.

Second Creek

The extreme northeastern corner of RMA (about 1 km^2) is part of the Second Creek drainage basin. Total basin size of Second Creek is about half that of First Creek, and it also is intermittent. Although Second Creek barely enters the extreme northeastern corner of Section 20, it does not actually cross RMA property. Second Creek is not currently connected to any onpost surface water body, but it previously fed a network of agricultural irrigation canals on what is now RMA land. At present, Second Creek is intercepted by O'Brian Canal.

Ditches and Canals

Besides First Creek, the only bodies of flowing water occurring within RMA are various canals and ditches entering from the south. These ditches are the Highline Lateral and Uvalda Interceptor, which enter from the south and southeast and feed into Lower Derby Lake; Havana Street Interceptor and Peoria Ditch, which enter near the South Gate and flow into Havana Pond; and Sand Creek Lateral, which enters west of Havana Pond and presently terminates north of the North Plants. The Army has recently entered into an agreement with the City and County of Denver to design improved drainage flow structures in the First Creek and Irondale basins.

Ditches and canals on RMA represent extremely limited aquatic habitat because of their highly irregular flows. However, most contain a small amount of water during much of the year, and they probably contribute aquatic invertebrates as well as water and sediments to the Lower Lakes. The Highline Lateral may be a route by which fishes enter RMA waters during periods of flow.

3.0 SAMPLING AND ANALYSIS PROGRAM

Biota investigations were conducted by ESE in two phases so that the sampling and analysis program could appropriately address current contamination sites and sources. Information developed in Phase I was used both to plan Phase II investigations and to provide a summary of past contamination problems as a basis for preparing the complete Biota RI.

The Phase II work plan was coordinated with the simultaneous investigations being conducted by MKE so that duplication of effort would be avoided. The vegetation and aquatic studies conducted by MKE provided information used to describe current conditions and provide supplementary information on the levels of biota contamination and related adverse effects. Rationale and a brief methodology for the Phase II tasks are presented in Section 3.2.

Development of the work plan was facilitated through technical discussions among representatives of the State of Colorado (Colorado Department of Health (CDH) and CDOW), federal government (U.S. Army and U.S. Fish and Wildlife Service (USFWS)), Shell Oil Company (Shell), and their respective contractors for biological studies in the Biota Assessment Subcommittee of the RI Committee (now the Biota Assessment Working Group (BAWG)) developed for this purpose. All studies and modifications were discussed in meetings of the BAWG. This committee was formed in January 1986, and continued to meet periodically throughout the biota assessment effort to discuss study objectives, methods, and preliminary results.

3.1 PHASE I INVESTIGATION

3.1.1 OBJECTIVES

A major Phase I objective was to develop a single database that included current and historical information on species presence and abundance; contamination sources and locations; contaminant types, concentrations, and distributions; biological effects of contamination; and other data pertinent to a comprehensive assessment of contamination in biota. Additional objectives of Phase I were to provide specific information on pathways for the movement of contaminants through the biota in conformance with the requirements of the NCP, to assess the potential for ecological effects and human health hazards resulting from contamination of biota, and to develop a work plan for any additional studies that were needed in order to provide an adequate basis for assessing biota contamination. This work plan was implemented as Phase II.

3.1.2 METHODS

A comprehensive effort was made to obtain all pertinent sources of information including RMA files, agency contacts, review of published literature, and other sources as suggested in Guidance on Remedial Investigations Under CERCLA (EPA, 1985i). Execution of this phase was accomplished in three tasks, each of which contributed to this preliminary assessment.

3.1.2.1 Preliminary Assessment

This task consisted of collection and compilation of data from all available regional sources and other pertinent literature. Major sources of information included the Rocky Mountain Information Center (RIC) and specific databases developed as part of the overall environmental assessment at RMA. Appropriate agencies were contacted, including the USFWS, CDOW, and local universities. Onpost data sources at RMA included reference collections of specimens, as well as unpublished data from biological information compiled since RMA's establishment in the 1940's. Pertinent sources have been cited in the text and are documented in Section 7 0 of this report.

A brief field survey was conducted within the defined study area to obtain information on the occurrence, distribution, and general abundance of key species of plants and animals. The distribution of major vegetation communities was initially mapped by MKE based on recent aerial photographs and limited ground-truthing. Subsequent field programs by both MKE and ESE included future refinement of the vegetation map. Incidental observations on habitat disturbance, plant or animal mortalities, and general site conditions were documented and incorporated into the general body of pertinent information.

3.1.2.2 Selection Criteria Development

General information on the toxicity and environmental behavior of chemical contaminants at RMA was compiled in relation to biological resources. A review of pertinent literature and consultation with the U.S. Army Medical Bioengineering Research and Development Laboratory personnel and other Army contractors resulted in the development of selection criteria for identification of contaminants of potential concern to biota and the selection of the 39 contaminants of concern. These selection criteria were based on the data documenting adverse effects of each potential contaminant of concern on biological resources and/or through them to humans. This task was integrated with the results of the Phase I contamination assessment to identify pathways to be developed and key species to be studied.

3.1.2.3 Contamination Assessment

The Phase I contamination assessment focused on accumulating and analyzing pertinent information on three major areas:

- o The species, populations, and interrelationships of biological resources on RMA and within the offpost study area;
- o The presence, distribution, and concentration of contaminants in the abiotic environment (e.g., soil, surface water, ground water, and air); and
- o The effects of contaminants on various components in the regional ecosystems.

Data from past studies, and preliminary data from current environmental studies were used to better define the present distribution of contaminants in the abiotic environment. Evaluating the effects of these contaminants on species and ecosystems included the development of food webs and defining pathways for the movement of contaminants through ecological systems. Seven subtasks were involved in the Phase I contamination assessment.

- o Species Inventory -- Species lists of plants and animals known to occur or potentially occur within the RMA region were compiled. Information on seasonal use (e.g., migratory visitor, seasonal breeder, etc.) was included to help with construction of food chains and food webs, identification of key species, and evaluation of potential biota contamination.

- Population Densities -- General information on the abundance of key species was developed to assist in determining important potential pathways of contamination movement within ecosystems and to provide a basis for estimating potential hazards to humans and other consumers in regional food webs.
- Food Habit Studies -- Available data from literature sources and regional contacts was supplemented with incidental observations during brief field visits to better define potential contaminant pathways.
- Food Webs -- Comprehensive (community) food webs were constructed for each major ecosystem. Information on predators and prey was organized into a computer database and analyzed to develop preliminary food webs. The database was later used in conjunction with information on general abundance and site specific food habits to determine major pathways and select key species for subsequent detailed food web analyses.
- Field Survey -- Brief field visits were conducted throughout the project study area (Section 2.3) to augment and update information obtained from published sources, internal Army documents, and agency/expert contacts. Any significant differences in vegetation cover, land use, or other significant features were recorded and incorporated into the Phase I contamination assessment. Incidental observations of wildlife species (e.g., location, behavior, feeding observations, etc.) were also recorded and used when appropriate.
- Chemical Inventory -- Information was obtained on chemical contaminants at RMA, including persistence, toxicity, bioconcentration/bioaccumulation potential, and distribution in the RMA environment. These data were used to preliminarily identify contaminants and areas of concern.
- Phase II Sampling Work Plan -- A Phase II work plan was developed in response to data gaps identified during Phase I. Components of this plan are presented in Section 3.2.

3.2 PHASE II INVESTIGATIONS

3.2.1 OBJECTIVES

The two major objectives of the Phase II biota investigations were:

- o To obtain quantitative information on the types, concentrations, and distribution of RMA contaminants in biota; and
- o To evaluate the adverse effects of RMA contamination in the abiotic environment on biological systems.

The program design was integrated with other ongoing studies so that concentrations of contaminants in abiotic media could be related to contaminant levels and effects in biota. Both direct effects (e.g., death, disease, reduced reproductive success) and indirect effects (e.g., alteration of food web relationships) were addressed. MKE data were used, as appropriate, to augment existing information, to describe current conditions (particularly in the Lower lakes), and to evaluate contaminant effects and contaminant pathways in biological systems.

3.2.2 METHODS

Several data deficiencies identified during Phase I led to the Phase II program. Because both the Army and Shell were conducting biological studies on RMA, it was agreed that these investigations would be coordinated to avoid duplication of effort and ensure that all information necessary for completion of the RI would be collected. Detailed study methods are described in the Task 9 Biota Assessment Final Technical Plan (ESE, 1988d, RIC#88243R05) and in forthcoming reports from MKE for their vegetation, wildlife, and aquatic ecosystem investigations.

New information obtained from Phase II biota field investigations and other sources (e.g., results of Phase I studies on contaminant distribution/levels in other media, newly available documents) was consistent with the general Phase I objectives, but at times led to appropriate modifications of specific study objectives within the Phase II Technical Plan. Additional studies that were instituted after Phase II began (e.g., bald eagle foraging and habitat use) are included as part of Phase II.

Statistical analyses were conducted on data to detect any population and/or chemical contaminant differences among sample groups. The general study design involved at least one RMA sample group and one offpost control. For less mobile species (e.g., earthworms, prairie dogs), onpost control groups were also sampled. In some cases, samples were collected from more than one site of potential contamination and from more than one season (e.g., winter collection of prairie dogs) because of eagle pathway concerns.

A variety of statistical analyses were used for population and non-chemical data, but non-parametric methods were used for all tissue contamination data because variances were consistently heteroscedastic and distribution was non-normal. The general analytical approach for each species was the same in that a separate Kruskal-Wallis one-way ANOVA was used initially for each contaminant, followed by a set of hierarchical a priori contrasts consistent with the experimental design. Where sample sizes were insufficient to detect differences, only descriptive statistics were prepared. Appendix B presents the details of all statistical analyses conducted on biota data.

Contaminant, population, and acetylcholinesterase (AChE) inhibition studies were designed to include equal numbers of samples from all onsite and offsite locations. This was not always achieved for a variety of reasons. Sufficient mallard eggs and fledglings could not be found in RMA lakes, and earthworms were difficult to locate in the South Plants. Brain samples for AChE testing were unequal, because some brains were damaged as a result of head shots while collecting animals for contaminant analysis. Where parametric assumptions could not be met, nonparametric statistical techniques still permitted analysis of results.

3.2.2.1 Collection Sites

Several of the investigations conducted in Phase II required sampling of contaminated and control areas in order to establish a relationship between conditions in onpost areas of contamination and background conditions in areas not exposed to RMA contamination. Onpost contaminated collection sites were selected based on the species being sampled and their proximity to areas of known or potential abiotic contamination (Section 36, Section 26, Lower Lakes). Onpost, as well as offpost control sites, were used. Onpost control areas were selected from areas where previous soil and ground water investigations revealed no contamination. Maps of collection sites from onpost contaminated and onpost control areas are provided in Section 4.3, along with the results of tissue analysis from biota collected from the individual sites. Collection site locations for offpost control areas are briefly described below. Offpost locations are shown in Figure 3.2-1.

Barr Lake State Recreation Area

Located approximately 5 mi north of RMA is a 1,900-acre (770 ha) lake lined with stands of cottonwood trees, marshes, and aquatic plants. The south end of the lake has been designated as a wildlife refuge providing habitat for mule deer and white-tailed deer, large numbers of wintering and breeding waterfowl, white pelicans, great blue herons, a wide variety of songbirds, and numerous raptors, including a nesting pair of bald eagles. Control samples collected from the Barr Lake area included ring-necked pheasants, kestrels and kestrel eggs, and earthworms.

Wellington State Wildlife Area

Located near the town of Wellington in northeastern Colorado, Wellington State Wildlife Area is 2,100 acres (850 ha) of ponds, marshlands, and grasslands. This area is owned and managed by the CDOW, primarily as a refuge for game birds. Control samples collected from this area include mallards and mallard eggs, cottontail rabbits, mule deer, and prairie dogs.

Pawnee National Grasslands

Located north of Greeley, Colorado, the Pawnee National Grasslands is a patchwork network of public grasslands managed by the National Forest Service. Rich in native flora and fauna, the Pawnee grasslands provide habitat for pronghorn antelope, jackrabbits, cottontail rabbits, small rodents, and raptors. Samples collected on Pawnee National Grasslands were cottontail rabbits, mule deer, and kestrels.

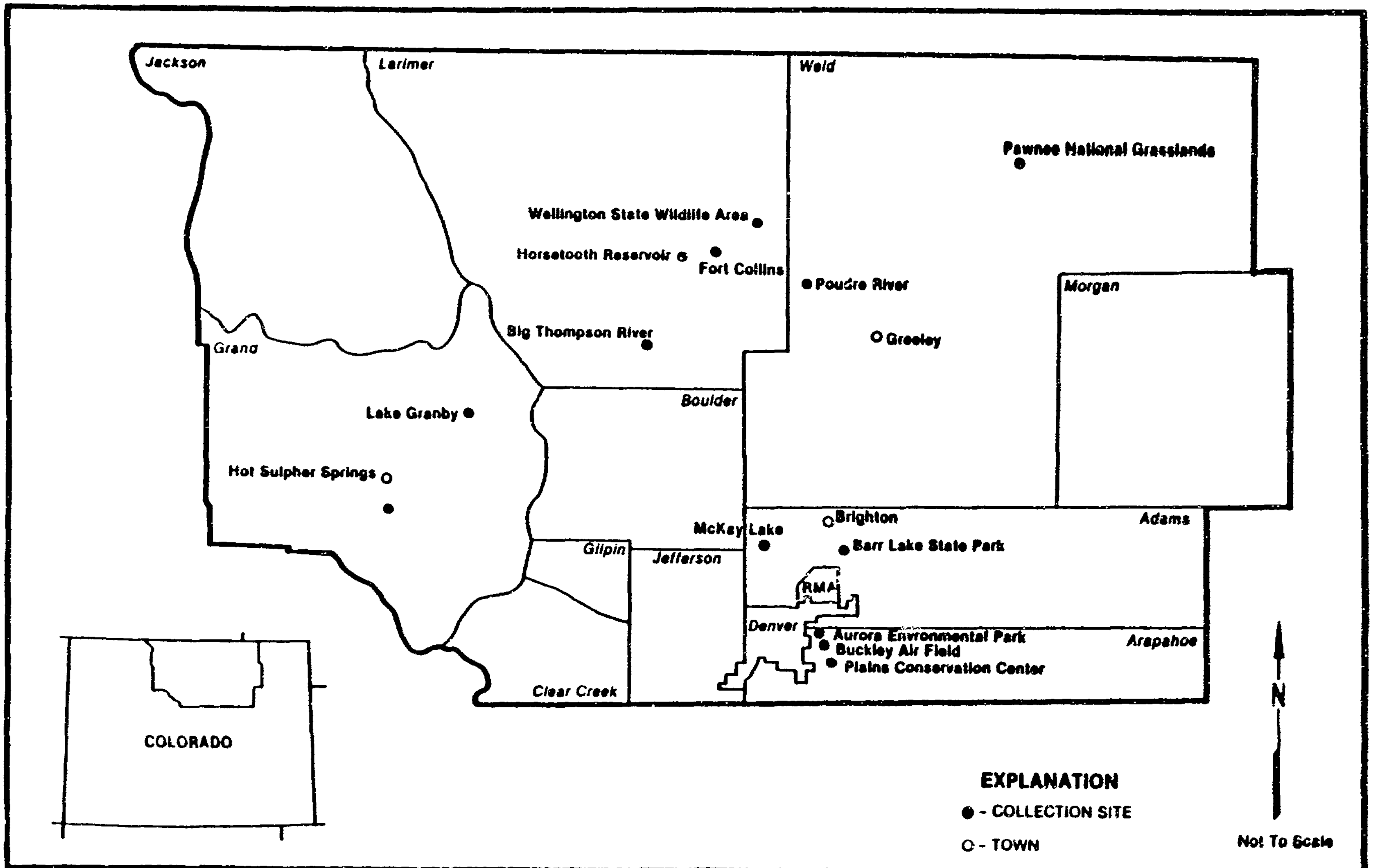

Figure 3.2-1
RMA OFFPOST CONTROL SITE LOCATIONS

SOURCE: ESE, 1988

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

Aurora Environmental Park

Located in the northeastern part of Aurora, Colorado, Aurora Environmental Park consists of grasslands and small cottonwood riparian areas borderin[illegible] Sand Creek which flows northwest through the park. This area was [illegible]d as a control area for vegetation and grasshopper transects and for th[illegible] collection of grasshoppers used as control samples in contaminant analy[illegible]s studies.

Buckley Air National Guard Base (Buckley ANG)

Located directly east of Denver, Colorado, Buckley ANG is an active Air National Guard Base providing runways, hangars, and training facilities for military aircraft. The landscape of the area consists of scattered barracks, military installations, and large areas of open grasslands. Prairie dogs, cottontail rabbits, jackrabbits, and wintering raptors are common on the installation. Buckley ANG was used for MKE offpost studies on prairie dogs, breeding songbirds, cottontails and jackrabbits, small mammals, and vegetation.

Plains Conservation Center (PCC)

Located south and adjacent to Buckley ANG, the PCC consists of 3 square miles of grasslands and prairie habitat in Aurora, Colorado. Scattered cottonwoods exist along Toll Gate Creek which bisects the PCC. Urban development is rapidly encroaching on the PCC from the west and south. The PCC provides habitat for pronghorn antelope, jackrabbit, cottontail rabbit, small rodents, and raptors. The PCC was used as an offpost control area in MKE studies for prairie dogs, breeding songbirds, cottontails rabbits, jackrabbits, small mammals, and vegetation.

McKay Lake

A small lake located in western Adams County, McKay Lake was used as the offpost control site in aquatic studies. This lake is comparable to the lower lakes in age, area, depth, adjacent vegetation, substrate, and water quality, and supports most of the same fish species as the lower lakes.

Other Areas

Kestrel and mallard brains used in acetylcholinesterase studies and eggs used in chemical analysis were collected from areas that had been previously used in similar studies conducted by the USFWS. Control sites used in the collection of kestrel and mallard eggs included areas in the vicinity of Fort Collins, Lake Granby, Big Thompson River, Monte Vista National Wildlife Refuge, Poudre River and Hot Sulphur Springs, Colorado (Figure 3.2-1).

3.2.2.2 Field Investigations

Studies were conducted to assess current conditions of biota in each major site of contamination and in their corresponding control sites. The goals of the field investigations were to detect and measure any differences between biota from sites of contamination and those from control areas and to assess whether detected differences might be attributable to RMA contamination. The populations of four species (black-tailed prairie dog, mallard, ring-necked pheasant, and American kestrel) were studied in greater detail. The prairie dog was of particular interest because of its importance as a raptor prey species.

Wildlife

A list of important wildlife species potentially occurring on RMA was initially compiled. A plant or animal species may be considered important for a variety of reasons. Federal laws have been enacted to protect species that are considered to be threatened with extinction. State laws have been passed to provide protection to species that are threatened on a local or statewide level. Species may be considered important based on their economic benefits, including recreational values or consumption by humans. Other species are considered important because of their potential negative impact on humans or other species. These include disease vectors, pests species, and species with expanding populations.

Species are considered important for the purposes of this report (Table 3.2-1) if they meet any of the following criteria:

- o Classified as federally threatened or endangered under the Endangered Species Act of 1973, as amended (species listed as candidate species for future consideration for inclusion on the Endangered Species List),
- o Listed as endangered by the State of Colorado,
- o Considered to be a Species of Special Concern by the CDOW (1985).

Table 3.2-1. Important Species Potentially Occurring On or Near Rocky Mountain Arsenal. In Order of Importance Within Groups According to USFWS and the Colorado Wildlife Workshop, 1985. (Page 1 of 4)

Common Name	Scientific Name	Status Federal	Status State	Observed on RMA
MAMMALS				
Black-footed ferret	*Mustela nigripes*	E	E	
Swift fox	*Vulpes velox*	C		X
Oppossum	*Didelphis virginiana*		SE	
Little brown bat	*Myotis lucifugus*		SP	
Big brown bat	*Eptesicus fuscus*		SP	
Desert cottontail	*Sylvilagus audubonii*		SD, G	X
Eastern cottontail	*Sylvilagus floridanus*		SN, G	X
White-tailed jackrabbit	*Lepus townsendii*		SD, G	X
Black-tailed jackrabbit	*Lepus californicus*		SN, G	X
Thirteen-lined ground squirrel	*Spermophilus tridecemlineatus*		SD	X
Spotted ground squirrel	*Spermophilus spilosoma*		SD	X
Rock squirrel	*Spermophilus variegatus*		SE	
Black-tailed prairie dog	*Cynomys ludovicianus*		SE, SP, SI, G	X
Fox squirrel	*Sciurus niger*		SP, SN, G	X
Northern pocket gopher	*Thomomys talpoides*		SD, SI	
Olive-backed pocket mouse	*Perognathus fasciatus*		SD	
Silky pocket mouse	*Perognathus flavus*		SD	X
Raccoon	*Procyon lotor*		SP, SE	X
Mink	*Mustela vison*		SE	
Spotted skunk	*Spilogale putorius*		SE	
Striped skunk	*Mephitis mephitis*		SE, SP	X
Bobcat	*Felis rufus*		SE	
Coyote	*Canis latrans*		G	X
Red fox	*Vulpes vulpes*		G	X
Gray fox	*Urocyon cinereoargenteus*		G	X
Badger	*Taxidea taxus*		G	X
Muskrat	*Ondatra zibethicus*		G	X
Mule deer	*Odocoileus hemionus*		G	X
White-tailed deer	*Odocoileus virginianus*		G	X
Pronghorn	*Antilocapra americana*		G	
BIRDS				
Bald eagle	*Haliaeetus leucocephalus*	E	E	X
Peregrine falcon	*Falco peregrinus*	E	E	X
Whooping crane	*Grus americana*	E	E	
Least tern	*Sterna antillarum*	E	E	
Piping plover	*Charadrius melodus*	E	E	
Ferruginous hawk	*Buteo regalis*	C	SD	X
Swainson's hawk	*Buteo swainsoni*	C		X
Western snowy plover	*Charadrius alexandrinus nivosus*	C	SD	

Table 3.2-1. Important Species Potentially Occurring On or Near Rocky Mountain Arsenal. In Order of Importance Within Groups According to USFWS and the Colorado Wildlife Workshop, 1985. (Page 2 of 4)

Common Name	Scientific Name	Status Federal	Status State	Observed on RMA
Mountain plover	Charadrius montanus	C	SD	
Yellow-billed cockoo	Coccyzus americanus	C	SD	
Long-billed curlew	Numenius americanus	C	SD	
Golden eagle	Aquila chrysaetos	H		X
Prairie falcon	Falco mexicanus	H	SD	X
Osprey	Pandion haliaetus	H	SD	X
Northern goshawk	Accipiter gentilis	H	SE	X
Cooper's hawk	Accipiter cooperii	H		X
Merlin	Falco columbarius	H		X
Burrowing owl	Athene cunicularia	H	SI	X
Eastern screech-owl	Otus asio	H		X
Upland sandpiper	Bartramia longicauda		SD	X
American bittern	Botaurus lentiginosus		SD	
Brown-headed cowbird	Molothrus ater		SN	X
Eared grebe	Podiceps nigricollis		SD, SI	X
European starling	Sturnus vulgaris		SN	X
American white pelican	Pelecanus erythrorhynchos		SE, SI	X
Chihuahuan raven	Corvus cryptoleucus		SD	
Mountain bluebird	Sialia currucoides		SD	X
Western grebe	Aechmophorus occidentalis		SD, SI	X
American dipper	Cinclus mexicanus		SI	
Loggerhead shrike	Lanius ludovicianus		SD	X
Great blue heron	Ardea herodias		SE, SI	X
Forster's tern	Sterna forsteri		SI	X
Fox sparrow	Passerella iliaca		SD,SI	X
Common nighthawk	Chordeiles minor		SD, SI	X
Yellow warbler	Dendroica petechia		SD	X
American avocet	Recurvirostra americana		SC	X
Solitary vireo	Vireo solitarius		SD	X
Black-throated gray warbler	Dendroica nigrescens		SI	
MacGillivray's warbler	Oporornis tolmiei		SI	X
Virginia's warbler	Vermivora virginiae		SI	
Common poorwill	Phalaenoptilus nuttallii		SD, SI	
Common yellowthroat	Geothlypis trichas		SD	X
Savannah sparrow	Passerculus sandwichensis		SD	X
McCown's longspur	Calcarius mccownii		SI	X
Snowy egret	Egretta thula		SD	
Black tern	Chlidonias niger		SI	X
Lewis' woodpecker	Melanerpes lewis		SD	
Yellow-headed blackbird	Xanthocephalus xanthocephalus		SD	X

Table 3.2-1. Important Species Potentially Occurring On or Near Rocky Mountain Arsenal, In Order of Importance Within Groups According to USFWS and the Colorado Wildlife Workshop, 1985. (Page 3 of 4)

Common Name	Scientific Name	Status Federal	Status State	Observed on RMA
Brant	*Branta bernicla*		G	
Canada goose	*Branta canadensis*		G	X
White-fronted goose	*Anser albifrons*		G	
Greater Snow goose	*Chen caerulescens*		G	X
Ross's goose	*Chen rossii*		G	
Mallard	*Anas platyrhynchos*		G	X
Mexican duck	*Anas diazi*		G	
Black duck	*Anas rubripes*		G	
Mottled duck	*Anas fulvigula*		G	
Gadwall	*Anas strepera*		G	X
Northern Pintail	*Anas acuta*		G	X
Green-winged teal	*Anas crecca*		G	X
Blue-winged teal	*Anas discors*		G	X
Cinnamon teal	*Anas cyanoptera*		G	X
American wigeon	*Anas americana*		G	X
Northern shoveler	*Anas clypeata*		G	X
Wood duck	*Aix sponsa*		G	X
Redhead	*Aythya americana*		G	X
Ring-necked duck	*Aythya collaris*		G	X
Canvasback	*Aythya valisineria*		G	X
Greater scaup	*Aythya marila*		G	
Lesser scaup	*Aythya affinis*		G	X
Common goldeneye	*Bucephala clangula*		G	X
Barrow's goldeneye	*Bucephala islandica*		G	X
Bufflehead	*Bucephala albeola*		G	X
Oldsquaw	*Clangula hyemalis*		G	
Common eider	*Somateria mollissima*		G	
White-winged scoter	*Melanitta fusca*		G	
Surf scoter	*Melanitta perspicillata*		G	
Black scoter	*Melanitta nigra*		G	
Ruddy duck	*Oxyura jamaicensis*		G	X
American coot	*Fulica americana*		G	X
Ring-necked pheasant	*Phasianus colchicus*		G	X
Chukar	*Alectoris chukar*		G	X
Northern bobwhite	*Colinus virginianus*		G	X
Scaled quail	*Callipepla squamata*		G	
Mourning dove	*Zenaida macroura*		G	X
<u>REPTILES</u>				
Milk snake	*Lampropeltis triangulum*		SE	
<u>AMPHIBIANS</u>				
Bullfrog	*Rana catesbeiana*		SN	X
Northern leopard frog	*Rana pipiens*		SD	X

Table 3.2-1. Important Species Potentially Occurring On or Near Rocky Mountain Arsenal. In Order of Importance Within Groups According to USFWS and the Colorado Wildlife Workshop, 1985. (Page 4 of 4)

Common Name	Scientific Name	Status Federal	Status State	Observed on RMA
FISH				
Rainbow trout	*Salmo gairdneri*		G	X
Northern pike	*Esox lucius*		G	X
Carp	*Cyprinus carpio*		G	X
Channel catfish	*Ictalurus punctatus*		G	X
Black bullhead	*Ictalurus melas*		G	X
Largemouth bass	*Micropterus salmoides*		G	X
Green sunfish	*Lepomis cyanellus*		G	X
Pumpkinseed	*Lepomis gibbosus*		G	X
Northern bluegill	*Lepomis macrochirus*		G	X
Black crappie	*Pomoxis nigromaculatus*		G	X
Red-ear sunfish	*Lepomis miggolophys*		G	X
Yellow perch	*Perca flavescens*		G	X
INVERTEBRATES				
Grasshopper	*Melanoplus sanguinipes*			X
Earthworm	*Apporectadea* spp.			X
Aquatic Snails	*Physella* spp.			X
	Gyraulus paruus			X
	Lymnaea spp			X

"Legend
- E = Endangered
- C = Candidate species
- S = Species of Special Concern
  - E = Educational, scientific, or recreational value
  - P = Pest, nuisance, or health hazard
  - D = small or declining populations
  - I = Indicator, ecologically sensitive species
  - N = Increasing, may negatively impact other species
- G = Game species
- H = High Federal Interest

Sources: Fairbanks, R.L. and J. Kolmer, 1976.
Colorado Division of Wildlife, 1981, 1982a, 1982b, 1985
Federal Register, 1985.
Dave Thorne, 1986a.
Morrison-Knudsen Engineers, Inc., 1988
Colorado List of Migratory Birds of High Federal Interest.

- o Used as game species that may be consumed by humans, or
- o Serve as species of special ecologic value (e.g., major prey species, predators, bioindicators, etc.).

Important wildlife species occurring on and near RMA were then surveyed by a variety of standard methods and by recording incidental observations in order to provide information on the occurrence, distribution, and relative abundance of important vertebrate and invertebrate groups. More intensive studies were used for select species of special ecological, regulatory, or economic importance, and those considered useful as potential indicators of contamination and habitat quality. Studies included both field studies and contaminant analysis. The following sections provide brief methodologies of field investigations and contaminant analyses on these select species.

Endangered Species

Endangered species received particular attention during Phase II studies. Black-footed ferret surveys were conducted throughout the nearly 5,000 acres of prairie dog towns during the summer of 1987 (July through September). The Survey was conducted at the request of the USFWS and was consistent with the guidelines for such surveys (USFWS, 1986). Surveys were conducted from vehicles at night using floodlights and spotlights. Survey teams were composed of two people, at least one of whom had received USFWS certification for black-footed ferret surveys. Detailed procedures are described in the Task 9 Biota Assessment Final Technical Plan (ESE, 1988d, RIC#88243R05). No ferrets were observed during these surveys.

A bald eagle winter roost was discovered by ESE field personnel in December 1986. Field studies were begun immediately on this endangered species to determine the feeding habits, habitat use, prey, and number of individuals using the roost. These studies continued through the winter of 1987-1988 to obtain additional pertinent information on the bald eagle's relationship to RMA contamination. Study components included midday censuses, roost counts, casting analyses, and feeding observations. The eagle studies were supplemented with regular recording of data on other raptors observed during eagle midday censuses. The results of studies conducted during the winters of 1986-87 and 1987-88 are summarized in the final Bald Eagle Study Report

(ESE, 1988b, RIC#88174R03) and discussed in relation to RMA contamination in Section 5.3 of this document. These investigations were supplemented by USFWS studies. Blood samples were collected by the USFWS from eagles during both winters, and telemetry studies were initiated during the winter of 1987-1988 to obtain data on the movements and habitat use of eagles throughout the region.

Prairie Dog Populations

Visual counts of black-tailed prairie dogs were undertaken in summer 1987 following methods described by Fagerstone (1983), and Fagerstone and Biggins (1986), and presented in detail in ESE (1988c, RIC#88204R01). Objectives of the study were to estimate minimum population densities and overall distribution of prairie dogs at RMA, and to determine the relationship of this distribution to major sites of contamination. A subsequent study was completed in January 1988 (ESE, 1988c, RIC#88204R01) to estimate the number of prairie dogs available as prey for raptors, including the bald eagle, foraging on RMA. Results from these studies complemented USFWS regional eagle studies and the simultaneous collection of prairie dogs for contaminant analysis. In Section 5.3 of this report, the results of both summer and winter studies are used to quantify the effects of RMA contamination on biota.

The January 1988 survey to determine minimum prairie dog density on RMA had the additional objective of evaluating the relative abundance of prairie dogs at the three major prairie dog towns. These data were analyzed to determine if known areas of contamination within the central town (that included Section 36 adjacent to Basin A) had depressed population levels that might be related to contamination. The same visual counting technique was used as in summer studies, but sampling was conducted during midday (1000 to 1300 hrs) when prairie dogs seemed to be most active at the surface. A total of 12 plots were observed for winter estimates. Plot locations for winter and summer surveys are indicated on Figure 3.2-2.

Acetylcholinesterase Inhibition

AChE inhibition testing was conducted on the brains of animals found dead on RMA and on the brains of other selected species for which brain tissue was

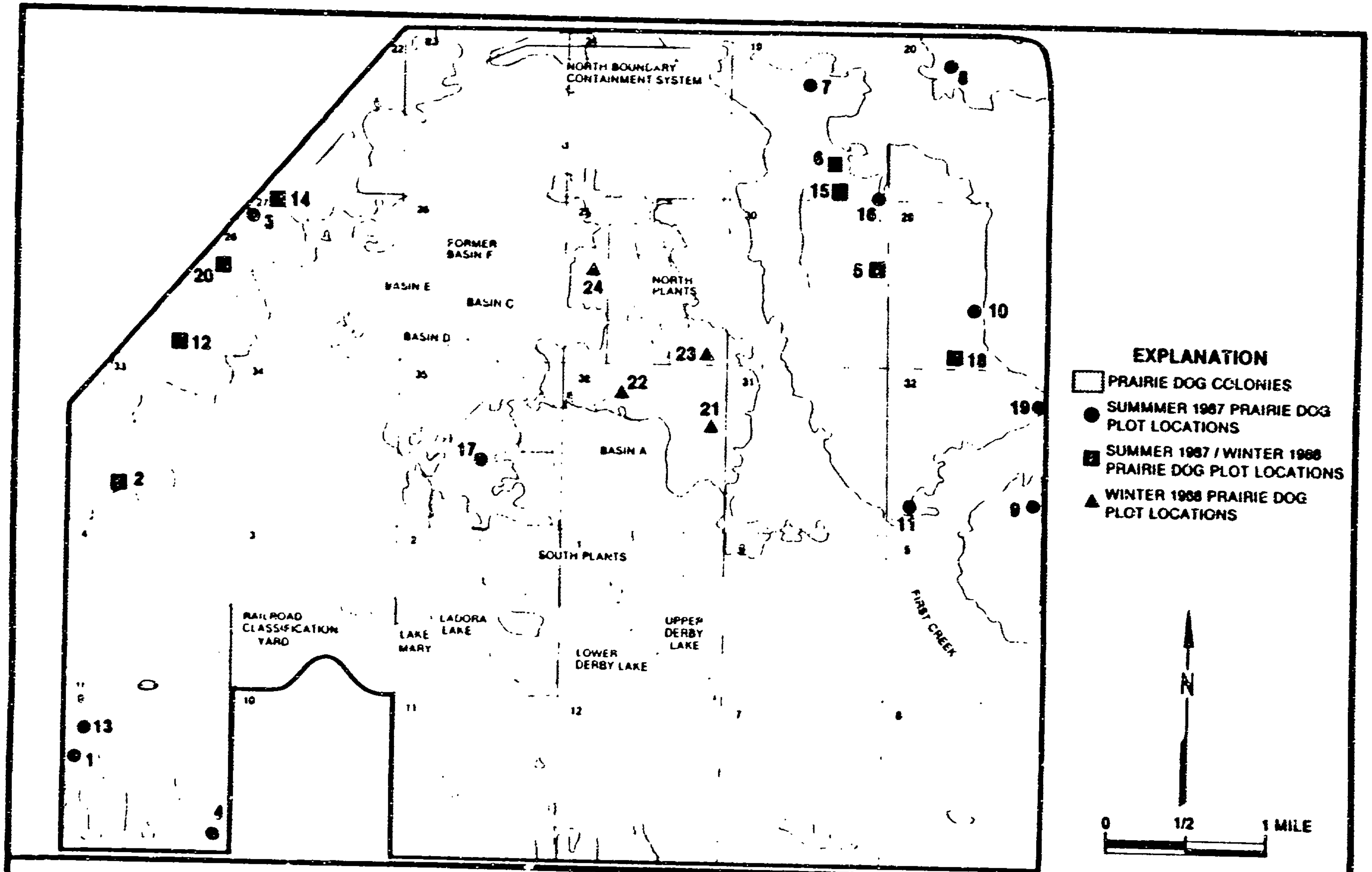

Figure 3.2-2
RMA PRAIRIE DOG COLONIES

SOURCE ESE, 1988

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

available. Species in intimate contact with the soil (e.g., prairie dogs) were of particular interest. This testing was performed using the basic procedures described in Ellman et al. (1961) as modified by Dieter and Ludke (1978) and Hill and Fleming (1982).

The brain tissue to be analyzed for AChE was frozen after collection, then partially thawed and homogenized with appropriate buffers. The assay procedures were performed in triplicate and a mean value calculated for each sample.

AChE analyses were run on 38 black-tailed prairie dog brains collected from four locations: offpost control (n = 8), onpost control (n = 11), Section 36 (n = 14), and the Toxic Storage Yard (TSY) in Section 31 (n = 5). All brains came from animals that were collected for contaminant analyses. Sample sizes varied due to the number of brains available for analysis (some animals were head shot during collection) and because some areas were sampled during summer and winter because of the concern regarding contaminant levels in the winter prey of bald eagles.

AChE tests were also conducted on cottontail brain tissue from three locations: onpost control (n = 11), offpost control (n = 8), and RMA Section 36 area (n = 8).

Invertebrate Populations

Three invertebrate groups were studied to evaluate potential contaminant effects on their populations. Invertebrates were selected for sampling because of their potential importance in regional ecosystems, because some species are known to bioaccumulate contaminants, and because they can serve as indicators of contamination effects. Earthworms were selected because of their role as detritivores in terrestrial ecosystems and their intimate association with the soil medium. Grasshoppers were selected because they are abundant herbivores in terrestrial ecosystems and provide a prey base for a variety of other wildlife, including American kestrels. Aquatic snails have a past history of contamination at RMA and were sampled because they have high bioaccumulation potential for organochlorine pesticide and metals contamination, and because of their potential importance as a pathway of contamination through aquatic food webs (e.g., their importance in the diet of waterfowl prior to egg-laying). Earthworms and grasshoppers were also sampled for contaminants, but the low volume and weight of snail samples precluded chemical analysis for this group.

Earthworm populations were sampled in the spring of 1987 by physical excavation of known soil volumes (1-m square plots dug to a depth of approximately 15 cm) and hand sorting to remove worms. Sample sites were selected in the South Plants, at an onpost control site in Section 5, and near Barr Lake offpost. Sites were selected on the basis of similar soil type. Other potential sample sites were eliminated on the basis of absence of vegetation and soil compaction which would limit interpretation of results. Sample plot locations were randomly selected within each study site except for the South Plants where sampling was limited to areas of suitable substrate.

Grasshopper abundance was estimated using a standard ocular technique (Thompson, 1986). Ten plots of 0.1 m^2 were established at 10-m intervals along five 100-m transects located in each onpost site of contamination and in offpost control areas at the Wellington Wildlife Area and Aurora Environmental Park. Surveys were conducted by walking along the transect and counting grasshoppers present in each plot. Grasshoppers for contaminant analyses were collected from the vicinity of population transects following population surveys. Pilot studies were conducted in the summer of 1986, followed by a complete field study in the summer of 1987

Snail samples were collected in five onpost lakes (Ladora, Lower Derby, Mary, North Bog, and Gun Club Pond) and two offpost control lakes at Wellington State Wildlife Area during the summer of 1986 and again during the summer of 1987. Snails and vegetative substrate were removed from ten 0.25-m^2 quadrants at randomly selected locations around each body of water. Snails were counted and weighed for each quadrant, and vegetation substrate was also weighed.

One of the control lakes sampled in 1986 was dry in 1987. A new lake at the Wellington Wildlife Area was sampled instead which prevented the use of a more powerful two way ANOVA. Separate one way ANOVA analyses were performed, using parametric and non-parametric methods, for each year, for snail weight and for snail numbers. Details of statistical analyses are reported in Appendix B of this report.

Avian Reproductive Success

Toxic chemical effects have been well documented for ducks and other birds inhabiting RMA. Based on both kestrel and waterfowl studies, avian mortality continued at RMA into the early 1980's, although recent effects appear to be less severe than in the past (McEwen and DeWeese, 1984, RIC#87091R03; Adrian, 1986). The three bird species selected for study were American kestrel (small raptor with limited home range and reported to be adversely affected by contamination on RMA in the past), ring-necked pheasants (terrestrial game species), and mallard (common waterfowl species in the region).

The avian reproduction success studies were a follow-up of the 1982-83 American kestrel investigations and was expanded to include nesting success of ring-necked pheasants and mallards. Study of brain acetylcholinesterase activity was also added in 1986. Collection of eggs and birds for determination of organochlorine concentrations was continued. The major objectives of the study were:

- o To determine organochlorine concentrations in and nesting success of American kestrels and to compare current findings with the 1982 and 1983 results and with data on concurrent controls as an indication of trends in terrestrial contamination at RMA.
- o To measure concentrations of xenobiotic chemicals in eggs and young of mallards and pheasants and examine the relationship to their reproductive success. Methods and study area locations are discussed in detail in the Final Biota Assessment Technical Plan (ESE, 1988).

The design of the kestrel study involved placing about 45 nest boxes to attract kestrels in each of three areas:

- Within the confines of RMA (Figure 3.2-3);
- A near-zone outside RMA boundaries but within 10 miles (Figure 3.2-4); and
- A control group in northeastern Colorado > 40 miles away (Figure 3.2-4).

One egg was collected for chemical analysis from each active nest box (Figure 3.2-5) in the three areas each year and the remaining eggs were left for observations on hatching success and production of young. A representative sample of young kestrels was also collected for chemical analysis prior to fledgling (one per nest from some of the nests in each area). Offpost control sites for kestrels were located north of RMA.

Ring-necked pheasant brood counts were conducted in both control and RMA areas from August 7 through 28, 1986 (Figures 3.2-6a and 3.2-6b). Each of four routes per area was counted six times during this period. Routes were each 6 miles in length and took from 25 to 42 minutes to traverse. During the census runs, age and sex of birds observed were determined if possible.

In 1984, a limited survey of waterfowl nesting success at RMA was conducted by USFWS (McEwen and DeWeese, 1985). Fewer nests and broods of young were found than were expected in the habitat available. A total of 36 eggs were collected for chemical analysis from 30 nests of three species -- mallard, Canada goose, and American coot. Twenty-one young birds of these same species plus redheads were also collected for analysis. Funding restrictions permitted organochlorine analysis of only 16 of the eggs and breast muscle from 12 of the young.

Waterfowl were observed on six RMA lakes and six control lakes in northeastern Larimer County during the period August 7 to 28, 1986 (Figures 3.2-7a and 3.2-7b). Total waterfowl of four groups, dabbling ducks, diving ducks, American coots, and Canada geese were counted. Young of the year could not be identified in all cases.

Mallard and pheasant nests were sought in all suitable habitat including the Lower Lakes, Gun Club Pond, and North Bog (Figure 3.2-8). The number of

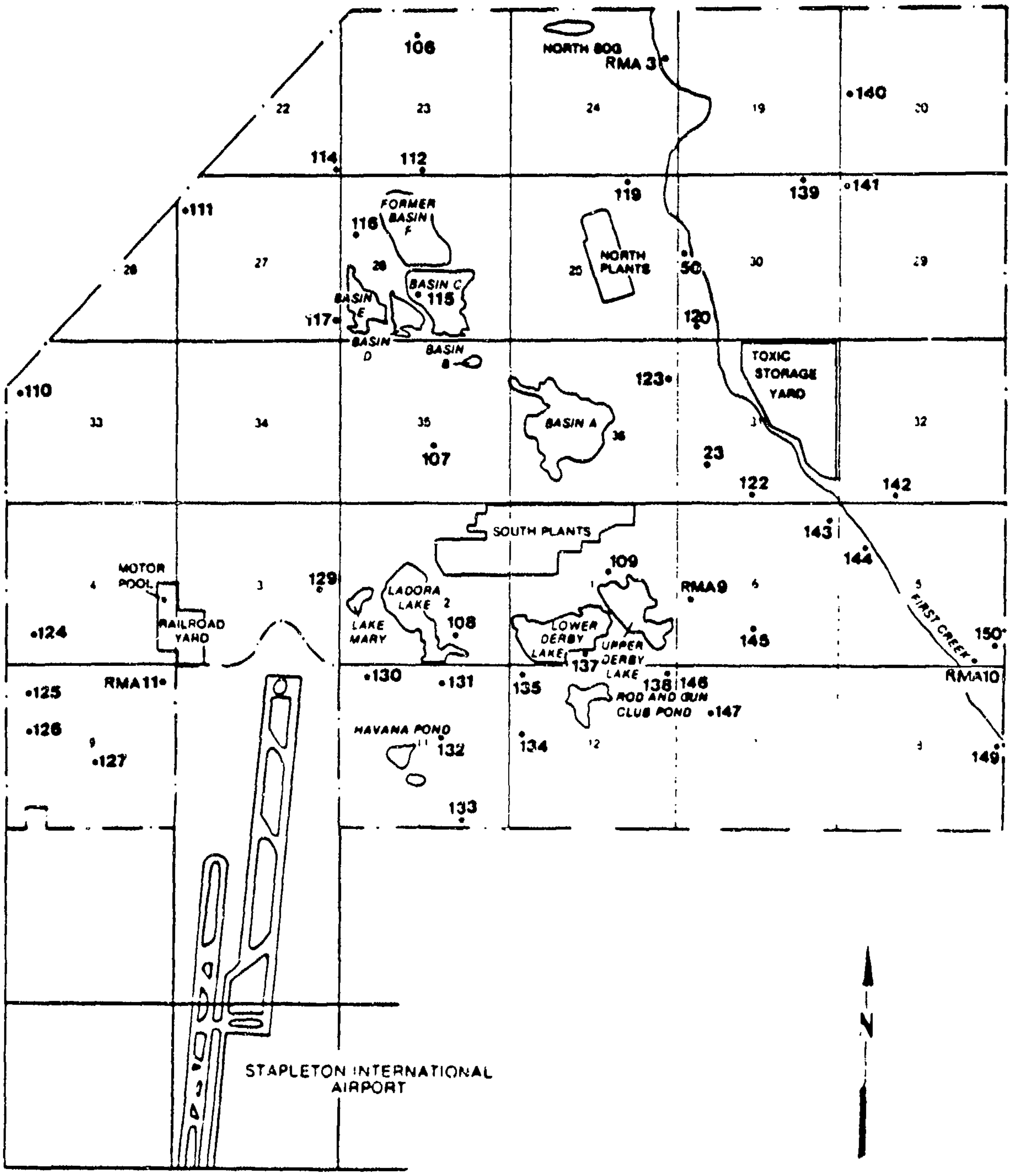

Figure 3.2-3
LOCATIONS AND NUMBERS OF AMERICAN KESTREL NEST BOXES ON THE RMA OBSERVED FOR PRODUCTIVITY AND CHEMICAL CONCENTRATIONS IN EGGS AND YOUNG IN 1986
SOURCE. ESE, 1986

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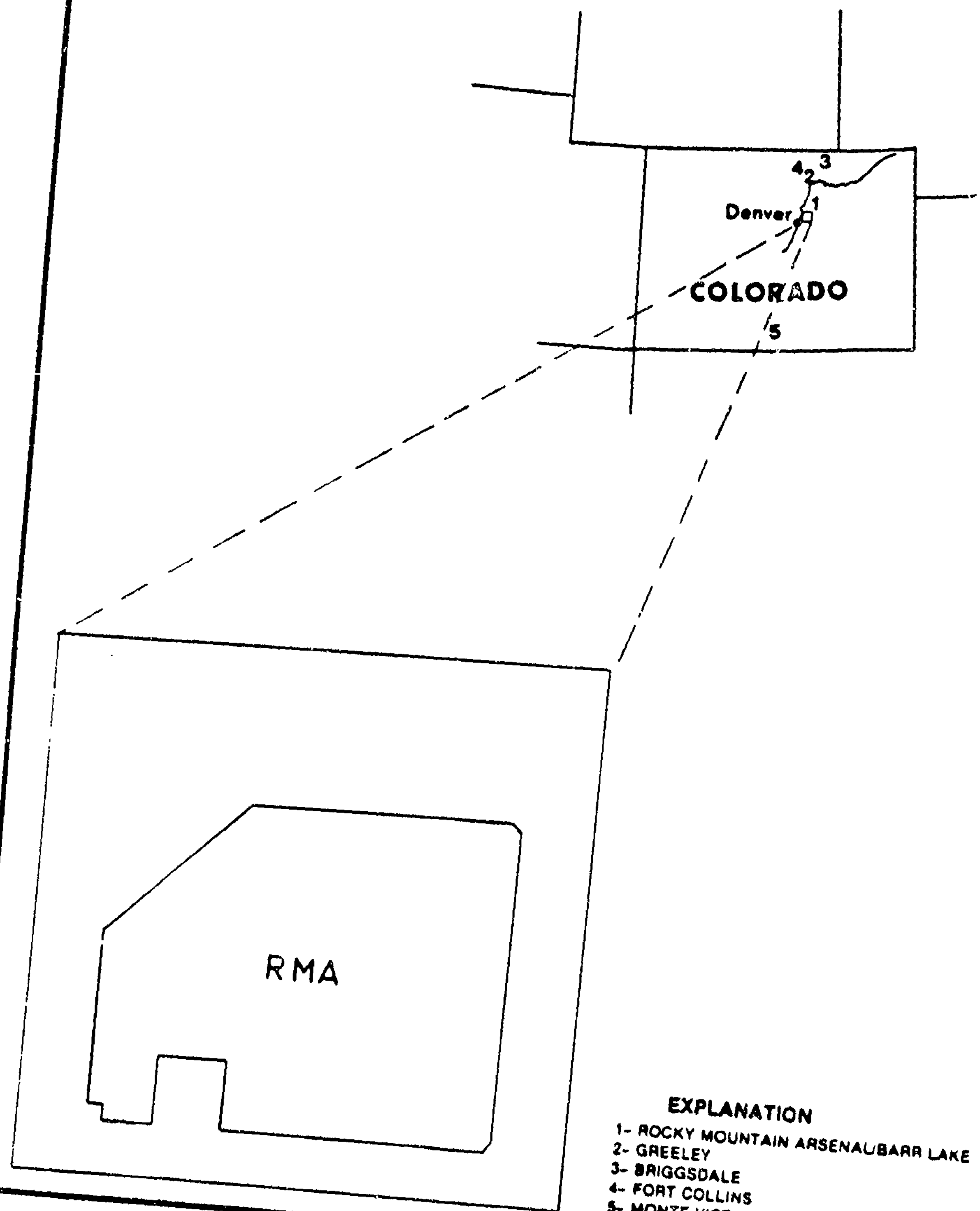
Aberdeen Proving Ground, Maryland



EXPLANATION

1- ROCKY MOUNTAIN ARSENAL/BARR LAKE
2- GREELEY
3- BRIGGSDALE
4- FORT COLLINS
5- MONTE VISTA REFUGE

Figure 3.2-4
OFFPOST KESTREL NEST BOX LOCATIONS

SOURCE: ESE, 1988

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Aberdeen Proving Ground, Maryland

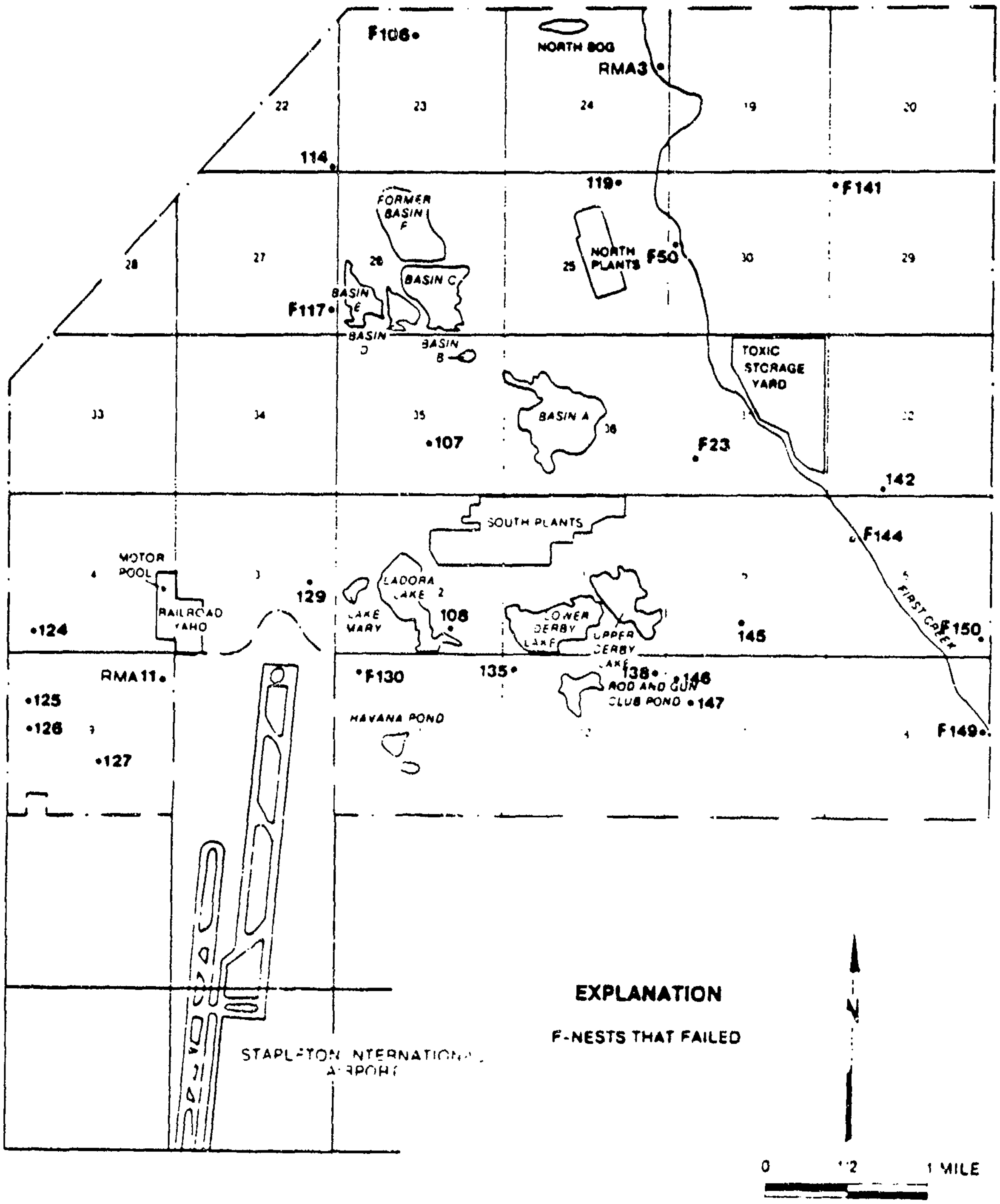

Figure 3.2-5
LOCATIONS OF ACTIVE KESTREL NEST BOXES ON THE RMA IN 1986
SOURCE: ESE, 1988

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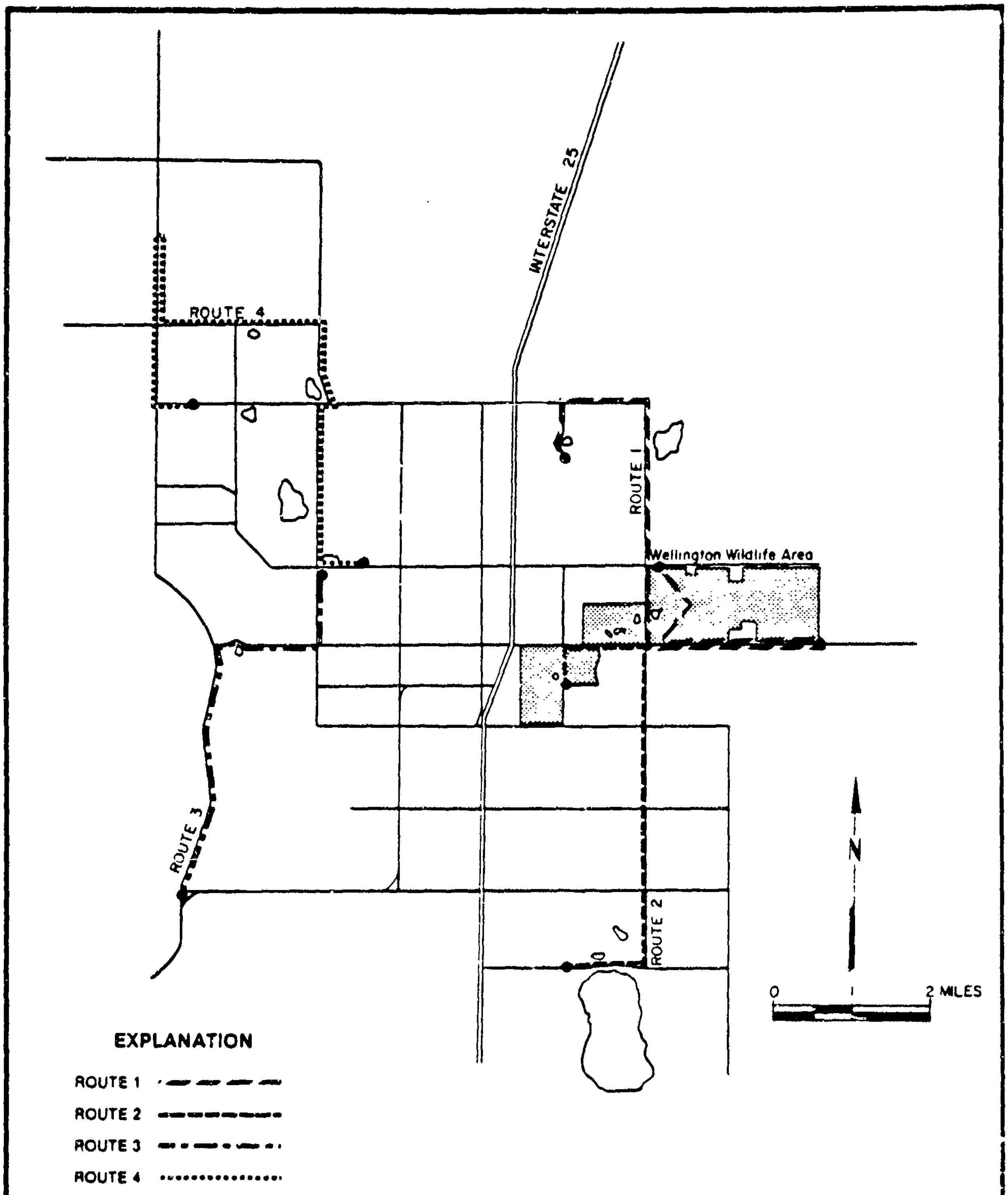

Figure 3.2-6a
LOCATIONS OF RING-NECKED PHEASANT BROOD COUNT ROUTES IN NORTHEASTERN LARIMER COUNTY (CONTROL) DURING 1986
SOURCE: ESE, 1988

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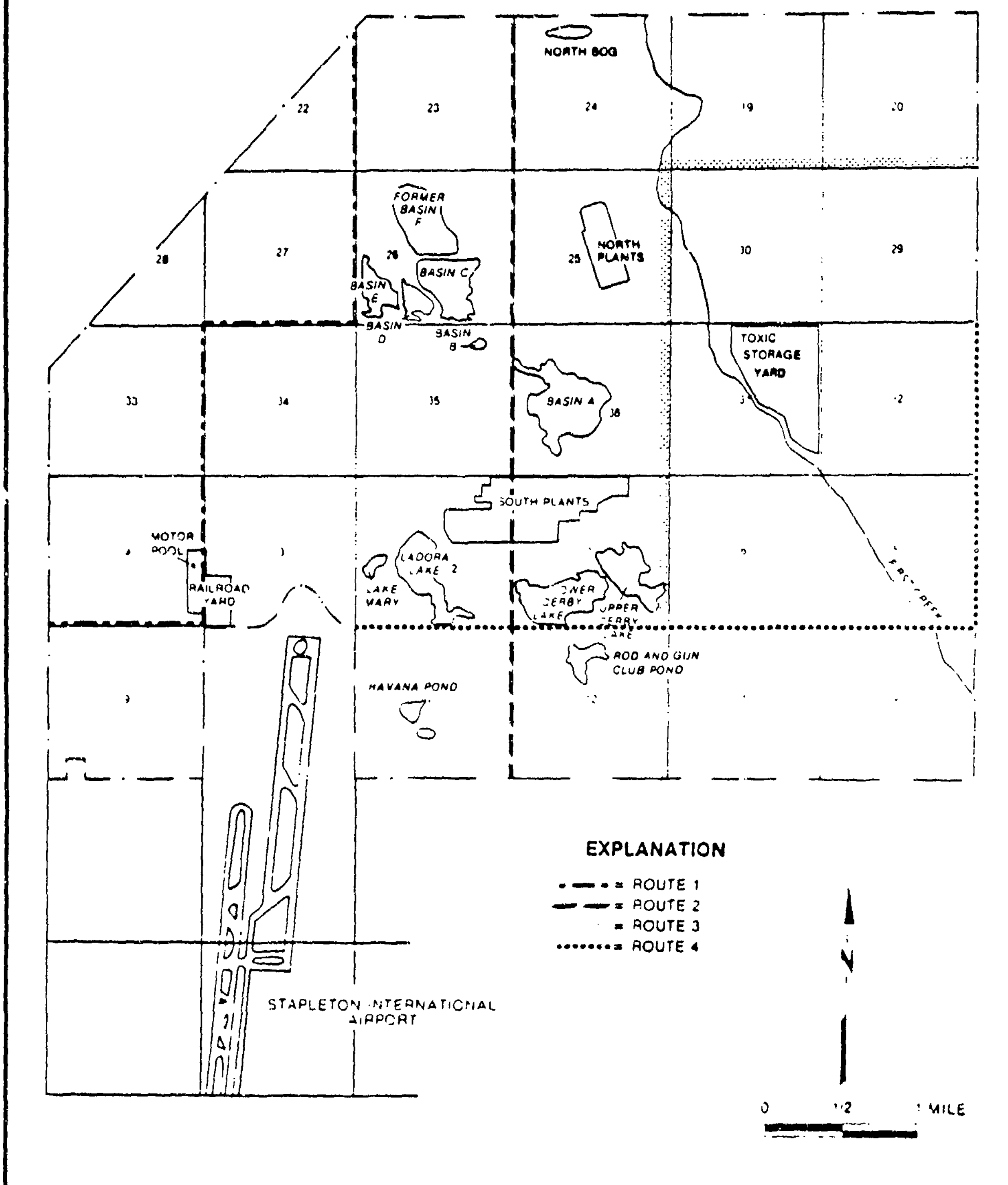

Figure 3.2-6b
LOCATIONS OF RING-NECKED PHEASANT BROOD COUNT ROUTES ON THE RMA DURING 1986
SOURCE: ESE, 1988

Prepared for:
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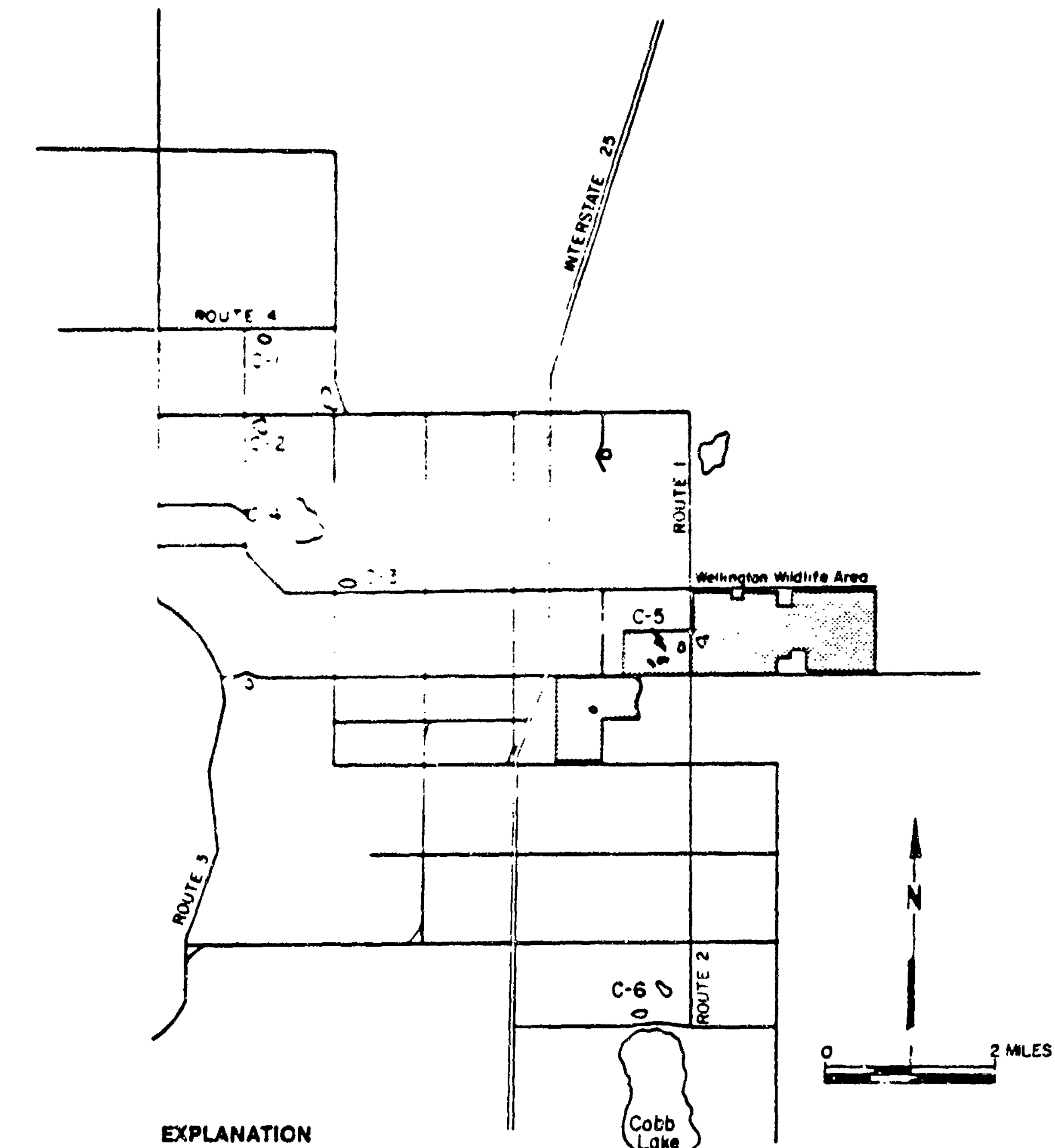
Aberdeen Proving Ground, Maryland



EXPLANATION

C-1	POND SOUTH OF ROAD 72
C-2	POND SOUTH OF ROAD 70
C-3	SMITH POND
C-4	WELLINGTON RESERVOIR #3
C-5	NORTH WELLINGTON WILDLIFE AREA PONDS
C-6	SOUTH WELLINGTON WILDLIFE AREA PONDS

Figure 3.2-7a
LOCATIONS OF LAKES FOR WATERFOWL COUNTS IN NORTHEASTERN LARIMER COUNTY (CONTROL) DURING 1986
SOURCE: ESE, 1988

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Aberdeen Proving Ground, Maryland

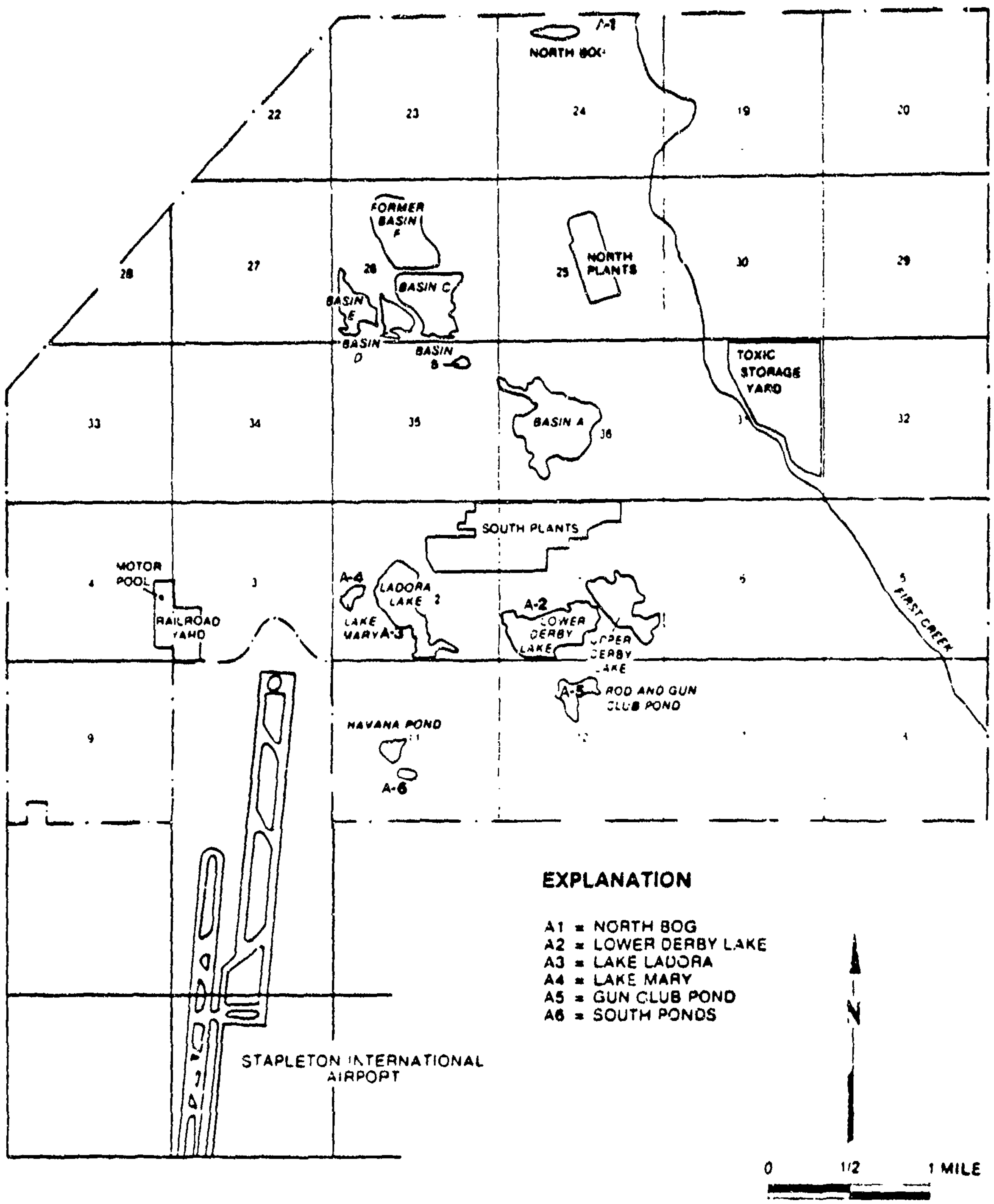

Figure 3.2-7b
LOCATIONS OF LAKES FOR WATERFOWL COUNTS ON THE RMA DURING 1986

SOURCE: ESE, 1988

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For Rocky Mountain Arsenal
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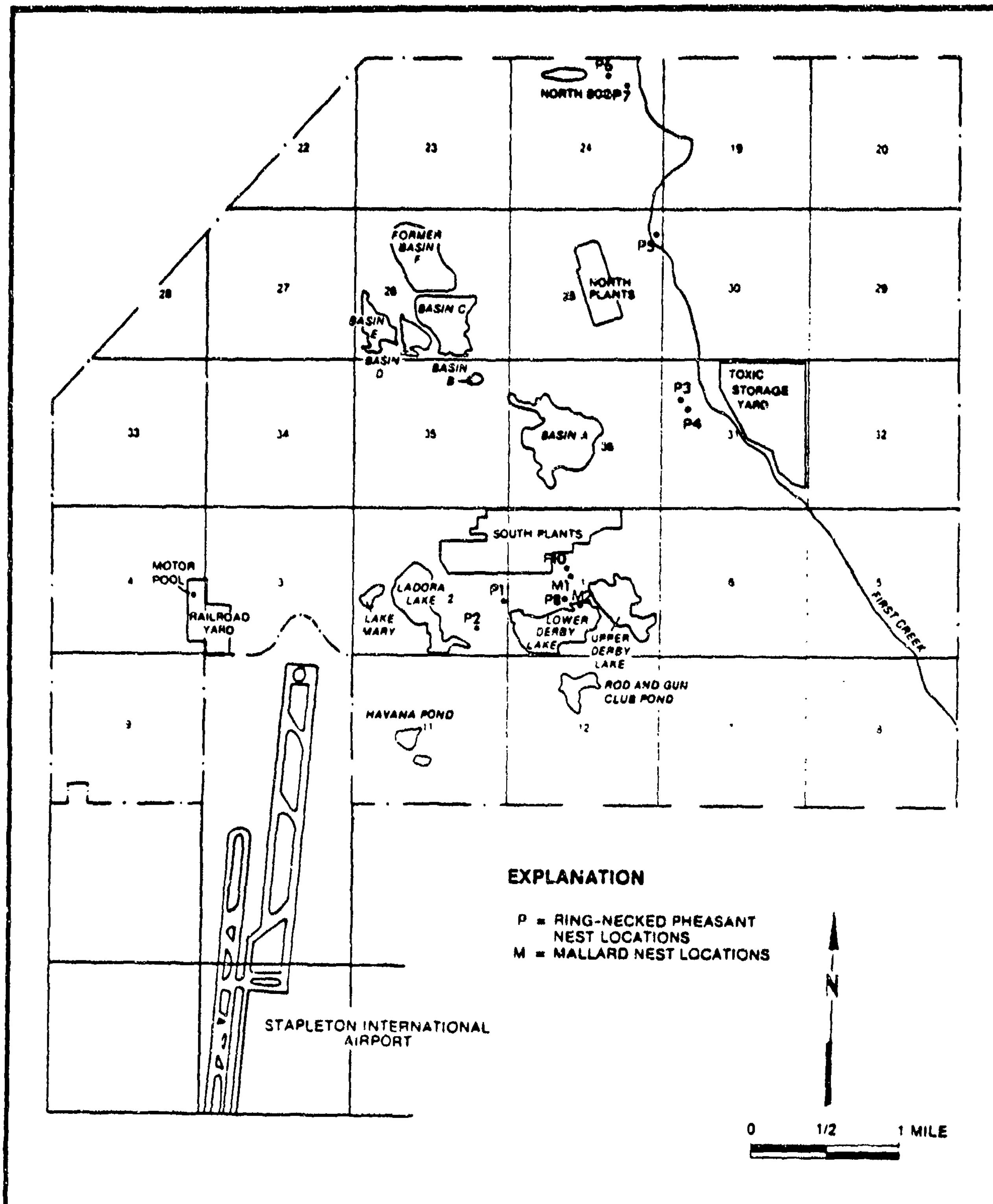

Figure 3.[illegible]-8
LOCATIONS OF RMA RING-NECKED PHEASANT AND MALLARD NESTS FROM WHICH EGGS WERE COLLECTED IN 1986
SOURCE: ESE, 1988

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eggs in the clutch was recorded and one egg was collected from each nest for contaminant analysis. Egg weight, volume, dimensions, shell thickness, and state of development were recorded for each egg collected. The nest was later rechecked to determine the fate of remaining eggs. Regular systematic mallard and pheasant brood surveys were conducted from June through July 1986 to determine brood size and successful fledging. One bird from each brood was collected from each successful nest for necropsy and chemical analysis.

3.2.2.3 Contaminant Analysis

The objectives of this study were to determine the concentrations and type of RMA contaminants in the tissues of key species of biota at RMA and at offpost control sites. Results of these analyses provided an inventory of contaminant levels in various biological components at RMA and distribution of contamination in important species and along major pathways throughout regional ecosystems. This information was used in evaluating possible contaminant effects (e.g., avian reproductive success, prairie dog population densities, raptor mortalities, and potential hazards to humans and endangered species) through the consumption of Arsenal contaminated biota. Species, tissues, and contaminants selected for study and the methods of analysis were discussed in detail in the BAWG meetings. Analyses of samples from onpost nonsource and offpost areas provided data to assess local (RMA) and regional background contamination levels, to compare levels of contamination in biota from contaminated sites with regional background levels, and to determine the extent of contamination in biota throughout RMA.

Biological tissue samples of selected species were collected for analysis from known sites of contamination on RMA, from nonsource areas onpost (for sedentary species), and from offpost control areas. Key species for analysis were selected based on the following criteria:

- o Are listed as federally threatened or endangered, or considered as a candidate species by the USFWS;
- o Are considered important components of regional ecosystems (e.g., abundant prey for other important species);
- o Contribute to representation of the range of trophic levels;

- o Are economically important (e.g., game and pest species); and
- o Represent a higher trophic level in food chains/webs in regional ecosystems.

The samples collected on RMA by the USFWS and made available for this study were evaluated to select those species that would provide additional information without duplication of samples being collected under the prescribed design. Tissues selected for analysis for each species were based on the probable fate of the organism within a food web or because of its particular status. Thus, for prairie dogs and other typical prey species the carcass, as consumed by higher predators, was analyzed. The head, feet, fur and gastrointestinal tract (stomach and intestines) were removed from such carcasses. Special care was taken to retain all body fat with the carcass. In animals such as cottontails that would also be consumed by humans (who eat primarily muscle), muscle tissue only was analyzed. Samples for chemical analysis from two other sources, animals found dead on RMA and samples collected by USFWS. The collection and preservation of animals found dead on RMA, particularly species that occurred at higher trophic levels and could not be otherwise collected without potentially adverse effects to their populations (e.g., raptors such as hawks, owls, and eagles), was an important portion of the contaminant analysis program.

Additional prairie dog samples were collected by Shell/MKE for tissue analysis. Prairie dogs were collected on RMA from sites near contamination (Section 26 and 36) and from areas removed from major sites of contamination (Sections 30, 27, and 9). Prairie dogs were also collected at Buckley ANG as an offsite comparison. All prairie dogs were collected in September and October 1986 and were maintained in ultracold storage (-30^{o}C) until the time of sample preparation immediately prior to analysis. Analyses were performed to USATHAMA certifications. Analytes were arsenic, mercury, aldrin, dieldrin, endrin, DDT, and DDE.

At the time of collection, each prairie dog was separated into three subsamples: skin and fur, skeletal muscle (meat), and viscera (liver, lungs, heart, and kidneys). At the time of analysis, the meat and viscera subsamples were combined for each prairie dog. This was done so that the results would reflect contaminant concentrations in the tissues preferentially consumed by predators, especially birds of prey.

Compounds selected as contaminants of concern to biota met the following criteria:

- o Present in the RMA environment above ambient concentrations;
- o Rated at least moderately toxic; and
- o Volume and persistence information indicate that the chemical was present i' the environment in sufficient quantity and/or for a long enough period of time to pose a hazard to biota.

Thirty-nine contaminants were selected for evaluation based on this approach (ESE, 1988d, RIC#88243R05). Toxicity assessments were prepared for all 39 contaminants of concern to biota (Section 5.1). These ' ssessments summarize pertinent information on the nature and extent of existing or potential hazard to wildlife.

From the list of 39 contaminants of concern, seven were identified as major contaminants of concern based on the following criteria:

- o Found in elevated levels in biota based on past studies;
- o Found in the physical environment for biota at RMA (soil, surface water, ground water at depths of less than 20 ft) based on current studies;
- o Occurred in high volumes and/or with an areal extent of >5 acres; and
- o Occurrence/concentration in tissues could be related to any known adverse effects.

The seven major contaminants of concern (aldrin, arsenic, DBCP, dieldrin, isodrin, and mercury) were selected for detailed pathways analysis.

Contaminants to be analyzed in biota tissue (target analytes) were selected from the list of major contaminants of concern. DDE and DDT, though not major contaminants of concern, were included as target analytes because of their environmental persistence and toxicity even though they did not meet the criteria of areal extent (>5 acres) in the biosphere based on the data available from Phase I water and soils studies. Two major contaminants of concern were not chosen as target analytes. DBCP, although toxic, does not bioaccumulate significantly, while isodrin, an analog of endrin, is converted to endrin by metabolic processes. The seven target analytes then are aldrin, arsenic, DDE, DDT, dieldrin, endrin, and mercury.

The methods for chemical analyses of selected tissues from key species for organochlorine pesticides (aldrin, dieldrin, DDE, DDT, and endrin) and metals (arsenic and mercury) were certified under the 1985 USATHAMA QA Plan. Additional information on chemical storage, processing, documentation, and analysis is provided in Section 4.0 of the Phase II Task 9 Biota Assessment Final Technical Plan (ESE, 1988d, RIC#88243R05). Table 3.2-2 lists the species, tissues, and chemicals selected for analysis. Detailed lists of biota and sample locations are provided in the Technical Plan and discussed further in Sections 4.0 and 5.0.

3.2.2.4 Contaminant Pathways and Acceptable Criteria Development
Food webs involving key species of concern (e.g., endangered species, economically important species, species representative of specific trophic levels, species at higher trophic levels, and important prey species) were developed for terrestrial and aquatic ecosystems at RMA. These webs were developed on the basis of food habits information from the literature, from gut content analysis for animals sampled at RMA, and from observations at RMA.

Toxicity assessments were prepared for all contaminants of potential concern to biota (Section 5.1). These assessments summarize pertinent information on the nature and extent of existing or potential hazard to wildlife. These data will be incorporated with information on the concentration and distribution of these contaminants in physical media, currently being developed under other environmental assessment tasks, in the onpost and offpost endangerment assessment tasks to provide a quantitative evaluation of RMA contaminant hazards to biota for each of the defined study areas.

The chemicals identified as major contaminants of concern based on their presence in the biosphere (aldrin/dieldrin, arsenic, DBCP, endrin/isodrin,

Table 3.2-2. Species and Contaminants for Tissue Analysis (page 1 of 2)

Species/Group	Locations*	As	Hg	CCPs*	DDE/DDT	Tissues
		Estimated Number of Samples Analyzed for				
Black-tailed Prairie Dog	RMA, Sec. 36 (sum)	8	8	8		carcass
	Control (on, sum)	8	8	8		"
	Control (off, sum)	8	8	8		"
	RMA, Sec. 36 (win)	5	5	5		"
	Tox. Yard (win)	5	5	5		"
	Control (on, win)	5	5	5		"
Desert Cottontail	RMA, Sec. 36	8	8	8		muscle
	Control (on)	8	8	8		"
	Control (off)	8	8	8		"
Mule Deer	RMA	9	9	9		muscle
	Control (off)	3	3	3		"
	RMA	9	9	9		liver
	Control (off)	3	3	3		"
Mallard	RMA		8	8	8	egg
	RMA		8	8	8	fledgling
	RMA		8	8	8	ad. carcass
	Control (off)		8	8	8	egg
	Control (off)		8	8	8	fledgling
	Control (off)		8	8	8	ad. carcass
Ring-necked Pheasant	RMA	8	8	8	8	egg
	RMA	8	8	8	8	juv. carcass
	RMA	8	8	8	8	ad. carcass
	Control (off)	8	8	8	8	egg
	Control (off)	8	8	8	8	juv. carcass
	Control (off)	8	8	8	8	ad. carcass
American Kestrel	RMA		10	10	10	egg
	RMA		10	10	10	fledgling
	Control (off)		10	10	10	egg
	Control (off)		10	10	10	fledgling
Earthworms	RMA, South Plants	3	3	3	3	composite
	RMA, control	3	3	3	3	"

Table 3.2-2 Species and Contaminants for Tissue Analysis (continued, Page 2 of 2)

Species/group	Locations+	Estimated Number of Samples Analyzed for As	Hg	OCPs*	DDE/DDT	Tissues
Grasshoppers	RMA, Sec. 36	3	3	3	3	composite
	RMA, Sec. 26	3	3	3	3	"
	RMA, control	3	3	3	3	"
	Control (off)	3	3	3	3	"
Aquatic Macrophytes	RMA Lakes		5	5		whole plant
	Control (off)		5	5		" "
Common Sunflower	RMA, Secs. 26 & 36	8	8	8	8	leaves, flowers
	Control (on)	2	2	2	2	" "
Morning Glory	RMA, Sec. 36	4	4	4	4	whole plant
	Control (on)	2	2	2	2	" "
Samples of Chance	RMA & offpost	50	80	80	50	liver and brain
USFWS samples	RMA & offpost	40	40	40	40	see text, Section 5.1

* OCP = the organochlorine pesticides (aldrin, dieldrin, and endrin).

\+ sum = summer
win = winter
on = onpost
off = offpost

Source: ESE, 1988

and mercury) were selected for detailed pathway analysis. The pathway approach was used to develop criteria levels in soil, water, and sediment for the protection of regional biota and to evaluate existing levels to determine the nature and extent of contaminant hazards to biota. Pathway Analyses for major contaminants of concern to biota are presented in Section 5.2 of this document.

Pathway Analyses involved a multiple food chain approach to address the possible bioaccumulation of major contaminants within food webs. The model incorporated information from published sources, regional contacts, and site specific data. Separate food webs were developed for terrestrial and aquatic systems.

The Pathway Analysis uses the lowest tissue concentrations that are correlated with adverse effects, and establishes acceptable ("no effects") criteria in water, sediment, and soil. The water ingestion pathway uses either a No Observed Effects Level (NOEL) or Lowest Observed Adverse Effects Level (LOAEL) for each contaminant, adjusted with daily water intake to yield an acceptable concentration in water. The lowest concentration provided by these two levels is used as the accepted no effects concentration in water. The no effects criteria for sediment were based on those for water. No effects levels for soils were also based on the NOEL and LOAEL adjusted as appropriate by a biomagnification factor. Details of the application of this approach are provided in Section 5.2.

The acceptable (no effects) levels are used in this document to evaluate potential adverse effects on biota as is appropriate for the biota segment of the RMA Remedial Investigation. This approach will be integrated with the endangerment assessment process and will lead to the development of potential cleanup criteria for biota.

3.2.2.5 General Methodology for Pathway Analysis

The pathway approach uses a bioaccumulation model first proposed by Thomann (1981) and modified to include multiple food chains in a food web. The model incorporates estimates of exposure by various organisms to contaminants in the physical environment and the potential for bioconcentration (concentration from direct exposure to water in an aquatic environment), bioaccumulation (concentration from water and from diet), and biomagnification (systematic increase in concentration as contaminants move through food chains to higher trophic levels).

Development of the models for particular sites proceeds in several steps. A food web is first constructed independently for each known or potentially contaminated site/ecosystem, based on all available information and using site specific data to the extent possible. Next, key species are identified on the basis of their status as threatened or endangered, economic, or commercial importance (e.g., game species), or because they are critical to the structure and function of the ecosystem (e.g., an important prey species). Sink food webs (food webs that include all food chains leading to a particular species) are then constructed. Wherever possible, all species at one trophic level are combined into the sink web of the species on the next higher trophic level.

Cleanup criteria for sediments and water are derived by tracing the biomagnification of contaminant residues with health effects data for organisms at the top of the food web, back through intermediate trophic levels to the abiotic environment. For purposes of the model analyses, all organisms are assumed to be in equilibrium with their environment (Figure 3.2-9).

The model (Thomann, 1981) is structured such that each level is a step in a food chain:

Level #1 $BCF_1 = C_b/C_w$ (1)

Level #2 $BAF_2 = BCF_2 + f_2BCF_1$ (2)

Level #3 $BAF_3 = BCF_3 + f_3BCF_2 + f_3f_2BCF_1$ (3)

Level #4 $BAF_4 = BCF_4 + f_4BCF_3 + f_4f_3BCF_2 + f_4f_3f_2BCF_1$ (4)

where: BCF_i = bioconcentration by level i

BAF_i = bioaccumulation by level i

C_b = concentration of contaminant in biota

C_w = concentration of contaminant in water

f_i = food term

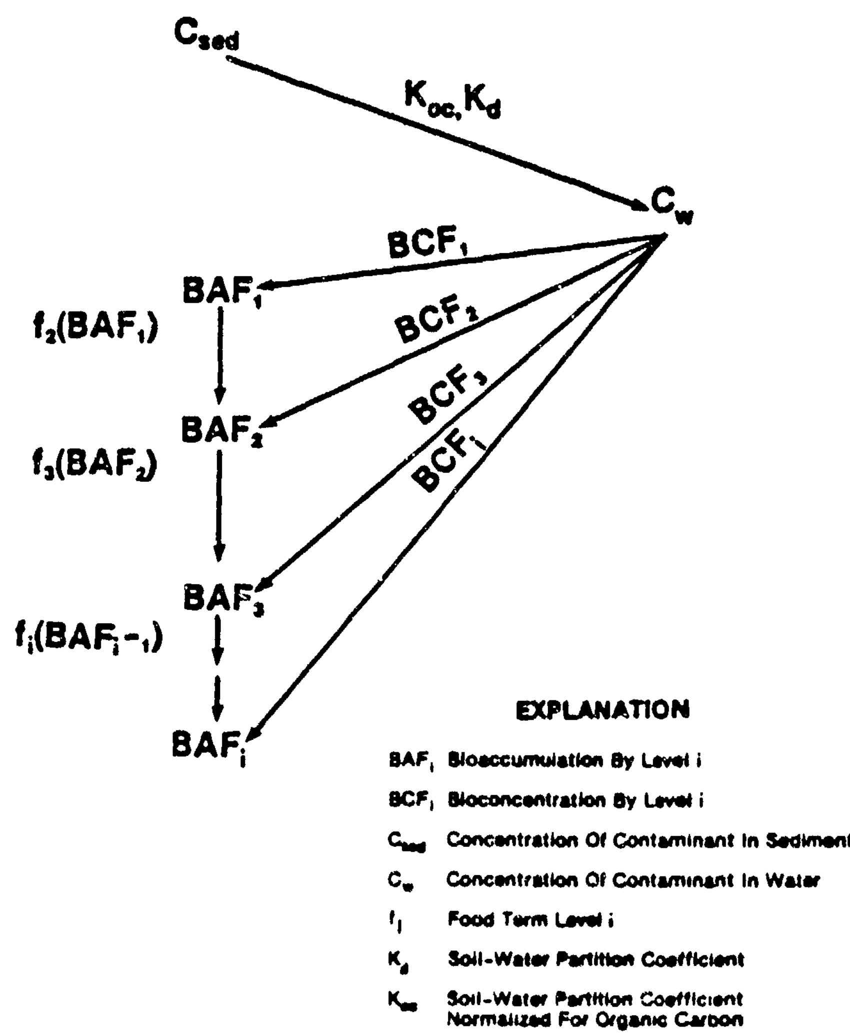

Figure 3.2-9
BIOACCUMULATION MODEL INDICATING CONTAMINANT CONCENTRATION AS A FUNCTION OF ACCUMULATION FROM WATER AND NET UPTAKE BY THE NEXT LOWER TROPHIC LEVEL
SOURCE: ESE, 1988

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

The food term (f_i) is dependent on the trophic level in question, and has been adapted from Thomann (1981) to describe bioaccumulation in an entire food web by using a percentage coefficient to adjust for multiple food chains. The f_i is calculated by the following equation:

$$f_i = \frac{\alpha \times R \times \%}{k_2} \qquad (5)$$

where: α = Assimilation efficiency, $\frac{\text{ug contaminant absorbed}}{\text{ug contaminant ingested}}$

R = Total daily diet, intake (g)/body weight (g)/day

k_2 = Depuration or loss rate, day^{-1}

% = Percent of (i-1) item in diet

For many contaminants, data are unavailable for parameters such as loss rates or assimilation efficiencies for each species in the Pathway Analysis. In these cases, judgement must be used to select the best data available from which to derive the parameters, and assumptions must be made that the parameters are applicable to all species in the analysis.

An example of a Pathway Analysis is based on the bald eagle sink food web (portion of the comprehensive ecosystem food web leading to a target species) and includes all major aquatic food chains leading to this selected sink species (Cohen, 1978). In such a Pathway Analysis, species in trophic levels below the target organism are selected by reviewing published information and by onsite observations on its food habits. The BCF values used can come from general published literature; however, previously collected and documented onsite water and tissue samples can be used when available to regionally calibrate the model.

As shown by the bald eagle example, a food web is simplified into its major food chains (pathways), e.g.:

Pathway 1: H_2O->Aquatic Plants->Mallard->Eagle

Pathway 2: H_2O->Aquatic Invertebrates->Mallard->Eagle

Pathway 3: H_2O->Plankton and Algae->Bluegill->Pike->Eagle

Pathway 4: H_2O->Aquatic Invertebrates->Bluegill->Pike->Eagle

Pathway 5: Soil->Plants->Small Mammals->Eagle

Pathways can be made more specific as food habit or toxicological data permit.

The percent of each item in the diet of the higher level organisms determines the importance of the pathway in contributing to residue accumulation. The dietary groups can be segregated further as data permits (e.g., invertebrates could be separated by family).

The lowest step in the food chain is assumed to be in equilibrium with the aquatic environment, which gives equation (1):

$$BCF = C_b/C_w \qquad (1)$$

where: C_b = concentration of contaminant in biota
C_w = concentr ion of contaminant in water

Organisms at this level are assumed to be autotrophic, such that residue accumulation can only result from uptake from water. The model was found to be more useful; however, if small aquatic organisms with varied feeding habits were included at Level #1 with the assumption that uptake from water (or surface adsorption) would outweigh uptake from diet to the point that uptake from diet was insignificant. Level #1 organisms usually consist of plankton, aquatic plants, and various aquatic invertebrates.

At Level #2 and higher, the food term must be calculated. Assimilation efficiencies and loss rates can either be found in the available literature, or estimated from available regression equations. They are rarely species specific, and assumptions must be made regarding interspecific similarity in contaminant uptake or loss. The total daily diet term for many wildlife species can be obtained or estimated from available food habits literature

When bioaccumulation factors are summed for each pathway, residue accumulation through all the food chains combined can be calculated for the target organism. Bioaccumulation factors are additive because bioaccumulation in each pathway represents residues from a fraction of the diet of the higher level organisms. The total residue accumulation from the food web (sum of the bioaccumulation factors) to the target organism is termed the Total Biomagnification Factor (Total BMF).

A Maximum Allowable Tissue Concentration (MATC) is based on available data indicating the lowest tissue concentration correlating with adverse effects. While the MATC is often unavailable for the target organism, especially when the target organism is an endangered species, a MATC can be extrapolated from data for similar wildlife species for chemicals for which a large database exists. For chemicals for which little information is available, the MATC must be extrapolated from health effects data on laboratory animals. When the MATC is divided by the Total BMF, a water concentration is derived that corresponds with the MATC in the target organism after transfer of water-borne contaminants through a food web (Tucker, 1986):

$$\frac{MATC}{\text{Total BMF}} = C_w \qquad (6)$$

Total residue accumulation for the target organism can be ultimately traced back through water to the sediment, because contaminants are assumed to enter the water compartment from sediment before being taken up by the biological compartment; i.e.,

$$C_w = \frac{Csed}{K_{oc} \times f_{oc}} \qquad (7)$$

Rearranging gives equation (8):

$$Csed = C_w \times K_{oc} \times f_{oc} \qquad (8)$$

where: Csed = concentration of contaminant in sediment

K_{oc} = soil-water partition coefficient normalized for organic carbon

f_{oc} = fraction of organic carbon

For chemicals where environmental fate is not dependent on organic carbon content, K_d is used in place of K_{oc} and f_{oc}.

Once a generalized food web has been developed for a particular species at a specific site it can be used to estimate cleanup criteria for a variety of contaminants. However, information on BCF, BMF, and BAF must be developed separately for each chemical in order to derive the appropriate values. Documentation for values used in actual criteria development is provided in the text for each Pathway Analysis.

The Pathway Analysis is a theoretical calculation involving many input parameters, each of which is known imprecisely. The combined effect that the uncertainty in each of these parameters may have on the final estimate of BMF has been evaluated through a statistical procedure known as Latin hypercube sampling.

The Latin hypercube sampling technique is a computationally efficient approximation of a Monte Carlo analysis. Monte Carlo is a procedure that determines the uncertainty in a calculated result (output) when the true values of the parameters used in the calculation (input) are uncertain. For example, consider the following formula:

$$z = ax^2 + by + c$$

where z = output, and

$a, b, c, x,$ and y = inputs.

Assume that a, b, and c are known precisely, but x and y are known imprecisely. If the probability density functions (uncertainty distributions) of x and y are specified, a Monte Carlo procedure can determine the probability density function of z. Monte Carlo operates by randomly selecting one possible value of x from its uncertainty distribution, a value of y from its uncertainty distribution, and then calculating z. By a random process, second possible values of x and y are selected and a second value of z is calculated and so on. A histogram of z values defines the uncertainties in the result. Monte Carlo is inefficient because it can require several thousand calculations. Latin hypercube sampling is a computationally efficient alternative that approximates the result of a Monte Carlo analysis but requires fewer (e.g., 100) trials to approximate the resultant distribution of z. The Latin hypercube sampling technique was developed by McKay et al. (1979) and has been used by Jaffe and Ferrara (1984) and Strayer and Pavlou (1987) for similar environmental applications. In this analysis, the sediment and water criteria are the outputs and the food chain-specific and chemical-specific input parameters are the inputs. A nonproprietary computer code compatible with an International Business Machines (IBM) personal computer (PC) was developed for this application following the procedures described by McKay et al. (1979) and Jaffe and Ferrara (1984).

The probability distributions of all site-specific and chemical-specific inputs are presented in the uncertainty analysis section for each contaminant. The input distributions are based on the information and data sources presented in the Pathway Analysis and statistical texts such as Gumbel (1958) and Barford (1967). The uncertainties in estimated chemical-specific parameters were defined based primarily on information presented by Lyman et al. (1982) as well as the original publications that present the regression analyses used for estimation.

3.3 SUPPLEMENTAL STUDIES

3.3.1 VEGETATION

Extensive studies of vegetation were implemented by MKE to develop descriptions of vegetation sites on RMA and at offpost control sites. These studies were supplemented by ESE investigations of additional sites. Field sampling techniques were identical, and investigators from ESE and MKE worked together to ensure that data would be collected in a comparable manner.

Vegetation studies at RMA included both quantitative and qualitative methods. Standard quantitative methods were employed for data collection regarding cover, height, frequency, and woody plant density. Qualitative methods included floristic surveys, phenological studies, and an evaluation of successional status. A detailed vegetation map of RMA was also prepared. Data were also collected at two offpost areas: Buckley Air National Guard (ANG) and the Plains Conservation Center. Methods are briefly described below. Detailed methods descriptions are provided in MKE's Final Vegetation Studies Technical Plan (MKE, 1986) and the Task 9 Biota Assessment Final Technical Plan (ESE, 1988d, RIC#88243R05).

A preliminary vegetation map was developed prior to initiation of quantitative studies, and was the basis for selecting vegetation sampling locations. Maps were prepared using a combination of aerial photographs and ground verification.

The sampling design for quantitative studies required 50 sample locations in each of the five major vegetation types (native perennial grass, crested wheatgrass, weedy forb, cheatgrass/native grass, and cheatgrass/weedy forb). For minor vegetation types on RMA, ten locations were sampled for each type. In addition to describing onpost vegetation and comparing it with offpost vegetation, the vegetation studies sought to determine if plant communities near the most contaminated sites on RMA differed from comparable communities growing in other portions of RMA. A similar sampling design was used based on 24 sampling sites distributed among three vegetation types in Section 36 (near Basin A) and six sites located among the same three vegetation types in Section 26 (near Basin F). A similar sampling design was followed at control sites located on Buckley ANG and at the Plains Conservation Center. This included two major and two minor vegetation types at Buckley ANG and two major and one minor type at the Plains Conservation Center.

Cover data were collected using 50-m point transects, and data were recorded by species. Two 50-m transects were sampled at each of the 50 sample locations in each major plant community and along one 50-m transect in each of the 10 sample locations in each minor community. Data computed for each sampling location included mean cover, relative cover (percent of total vegetation cover), frequency (number of transects of occurrence divided by total number of transects), and relative frequency (percent of total number of transects of occurrence by all species). Relative cover and relative frequency were summed to obtain an importance value for each species. Height data were collected for the most prominent species at each site by measuring individual plants at 10-m intervals along the 50-m transect. Density data for shrubs, subshrubs, yucca, and cacti were obtained by counting the number of individuals occurring within 1 m of the 50-m transects.

To the extent possible, voucher specimens were collected in triplicate. Observations on phenology (i.e., progression of plant development during the growing season) were recorded at 10- to 15- day intervals at all three study locations. Assessments were made regarding stages of vegetative growth, flowering, fruiting, dissemination, senescence, and regrowth.

Successional status was evaluated by reviewing aerial photographs taken in 1937, 1943, 1951, and 1974, and comparing them with vegetation patterns observed in 1986. Existing vegetation was also compared to published models for successional development in the Great Plains region.

The following subsections briefly describe the major and minor vegetation types at RMA, and what is known about their ecological or historical relationships. Summaries of quantitative information for cover, production, and woody plant density are presented in Table 3.3-1. All vegetation types described in the following sections are presented in Figure 2.3-2.

Weedy Forbs

The weedy forb community covered approximately 900 ha, or about 13 percent (%) of the total area of RMA. Although widespread, weedy forbs were most conspicuous in the northern portions of the RMA. The dominant weedy forb species at RMA were summer-cypress (Kochia) and morning glory (field bindweed), which accounted for 32.3 and 14.5%, respectively, of the total vegetation in the weedy forb community. In general, Kochia tended to dominate in sites without prairie dogs, whereas morning glory was more prevalent in prairie dog towns. Other common species in the weedy forb community included cheatgrass, scarlet globemallow, and prickly lettuce. Together, these three species provided 15% of the plant cover in the weedy forb type. Of the five major species, only scarlet globemallow is a native prairie species. Total vegetation cover in the weedy forb type was 29.6%, with 21.8% bare soil and 48.6% litter. Total production averaged 121 grams per square meter (g/m^2).

Species with the greatest average heights along the transects tended to be tall gaura and annual sunflower. However, tumble mustard, tansy mustard, and prickley lettuce were the more common tall species. All of these are

Table 3.3-1. Summary of Quantitative Vegetation Data for Major Vegetation Types, Rocky Mountain Arsenal, 1986

Type	Plant[1] Cover (%)	Production[2] (g/m^2)	Woody[3] Plant Density (no./ha)	Number[4] of Species	Number[5] of Samples
Weedy Forb	29.6	121.0	334	111	53
Cheatgrass/ Weedy Forb	45.8	140.3	249	126	79
Cheatgrass/ Perennial Grass	40.3	104.2	165	115	56
Native Perennial Grass	34.5	96.7	603	133	73
Crested Wheatgrass	28.5	99.7	126	101	50

1 All herbaceous lifeforms combined.

2 All herbaceous lifeforms combined: current year's above-ground growth.

3 Includes shrubs, subshrubs, and succulents.

4 Observed within the sampled stands.

5 Randomly selected.

coarse and difficult for prairie dogs to graze. The effect of grazing by prairie dogs is illustrated by Kochia, which had mean heights ranging from less than 10 centimeters (cm) in prairie dog towns to as much as 75 cm in other areas. Woody plants were a minor component in this vegetation community. Mean cover by all woody plants was less than 1%, and mean density of woody plants was only 334 per ha. Bushy eriogonum, a subshrub, was the most common woody species.

The weedy forb type is an early successional stage community that occurs as a result of severe disturbance. The limited perennial grass component present in the weedy forb community after nearly 50 years of succession in some parts of RMA (e.g., abandoned cultivated lands) suggests that the successional process is proceeding slowly or being periodically interrupted.

Cheatgrass/Weedy Forbs

The cheatgrass/weedy forb community was the most extensive vegetation type at RMA covering approximately 1,550 ha or about 22% of the area. As the name of the type suggests, the overwhelmingly dominant species was cheatgrass, an introduced weedy annual, that accounted for 63.8% of the vegetation cover. Secondary dominants were weedy forb species, including morning glory, bristle thistle, and prickly lettuce. These four species accounted for 81% of the total cover by vegetation in the cheatgrass/weedy forb type. Perennial grasses provided only 6.4% of the vegetation cover within the cheatgrass/weedy forb community. Mean total vegetation cover in the cheatgrass/weedy forb type was 45.8%, and cover by bare soil was only 4.9%. The remainder of the ground surface was covered by cheatgrass litter (i.e., remnants of the previous years growth). The dominance by cheatgrass can also be seen in the production data. Mean production of cheatgrass was 70.2 g/m^2 or 50.8% of the total (140.3 g/m^2). Shrubs were rarely encountered in this association. Mean shrub density was only 249/ha, with bushy eriogonum contributing 72% of the total shrub cover.

As with weedy forbs, cheatgrass/weedy forb communities have resulted from past disturbance. Once cheatgrass becomes established, it is a highly aggressive competitor and can delay or potentially even preclude succession to more desirable prairie communities.

Cheatgrass/Perennial Grasslands

Cheatgrass/perennial grassland communities occurred throughout RMA, but not as commonly as the cheatgrass/weedy forb type. Cheatgrass/perennial grass covered 780 ha, or 11% of RMA. The two types were similar in that cheatgrass dominated both, although cheatgrass comprised only 57.5% of the total vegetation cover in cheatgrass/perennial grassland. Three perennial grasses (sand dropseed, red three-awn, and needle-and-thread) occurred as secondary dominants, and total perennial grasses accounted for 28.0% of the plant cover in the cheatgrass/perennial grassland community, compared to only 6.4% of total vegetation cover in the cheatgrass/weedy forb type. Morning glory was also an important component, although forbs accounted for only 14.2% of the vegetation cover. Total vegetation cover in this type was 40.3%, slightly less than the amount in the cheatgrass/weedy forb areas. Bare soil was only 3.9% and litter accounted for 55.8% of the cover. Most of the litter consisted of the previous years growth of cheatgrass.

Heights of plants growing in the cheatgrass/perennial grass communities were comparable to those measured for the cheatgrass/weedy forb type. Mean height for cheatgrass was 27 cm, compared with 31 cm in the cheatgrass/weedy forb type. Few shrubs occurred in this type: mean total shrub density was 165/ha. The most common woody plant was bushy eriogonum, but two succulents--plains prickly pear and yucca--were about as abundant.

Cheatgrass had a mean production of 42.9 g/m^2, compared to 32.5% for perennial grasses. Total production was 104.2 g/m^2. This value is lower than for the two previous types, due in large part to lesser amounts of tall weedy forbs.

Native Perennial Grassland

Native perennial grassland was scattered over RMA in patches generally smaller than for the three preceding communities. However, native perennial grassland covered 1,400 ha or 20% of RMA. The largest area of native grasses is near the west-central portion of RMA. Dominant species in the native grasslands included prairie grasses such as blue grama, sand dropseed, needle-and-thread, western wheatgrass, and red three-awn. Native perennial grasses combined provided 57.5% of the total vegetation cover, although cheatgrass was the single most prevalent species in the native perennial grassland type. In contrast to the early successional types, forbs (both annual and perennial) were a minor element in this community. All forbs together accounted for only 19.8% of the total cover, which is characteristic of native grasslands. Mean total vegetation cover was 34.5%, and cover by bare soil was 8.6%.

Mean heights of the dominant grass species ranged from 15 to 45 cm. Tall forbs occurred in this type, but less so than in the early successional types. Shrubs were somewhat more common in this type. Mean density of woody plants and cactus was 603/ha; bushy eriogonum and plains prickly pear accounted for 82.3% of this total density.

Some areas of cheatgrass/perennial grasslands probably represent a mid-successional stage of development, resulting when perennial grass species (especially sand dropseed) are able to invade stands of cheatgrass. This could happen in areas that have remained undisturbed for sufficient periods, or where soil conditions are favorable. The fact that cheatgrass accounts for less cover and production in cheatgrass/perennial grassland than in cheatgrass/weedy forb areas probably is due in part to competition from perennial grasses. Other areas of cheatgrass/perennial grassland apparently represent degraded native ranges that have been invaded by cheatgrass. This is indicated where the perennial grasses are late-successional species such as blue grama or needle-and-thread.

Whereas cheatgrass had the greatest individual cover, several native grass species had higher production values. Perennial grasses accounted for 60.9% of the total production (96.7 g/m^2). Perennial forbs accounted for 15.1% of the total, and annual forbs accounted for 10.0%.

Most stands of native grassland on RMA probably are remnants of original, presettlement prairie. They may have been considered poor sites for agriculture and; thus, never tilled, or they may have been left uncultivated in order to support grazing. A few stands of native perennial grassland on RMA appeared to represent succession following disturbance. Such areas were dominated by red three-awn and tend to have relatively low species diversity.

Crested Wheatgrass

Stands of crested wheatgrass occurred throughout RMA and were nearly as extensive as native perennial grasslands, covering 1,330 ha or 19% of RMA. Crested wheatgrass was highly dominant in this type, contributing 71.9% of the total vegetation cover. Other conspicuous species included cheatgrass, sand dropseed, and field bindweed. Mean vegetation cover was 28.5%, and cover by bare soil was 4.7%. Litter consisting of the previous years growth of crested wheatgrass comprised 76.8% of total ground cover in the crested wheatgrass community. Mean height for crested wheatgrass was 42 cm. Because of the strong dominance by this species, the stands tended to be very homogeneous in height. Mean production of crested wheatgrass was 82.6 g/m^2 out of a total of 99.7 g/m^2. The remainder of the production was distributed among 27 species.

Woody plants and succulents occurred to a very limited extent. Mean density of woody plants and succulents was only 126/ha, mostly contributed by yucca and two species of prickly pear.

Crested wheatgrass is an introduced species that has been widely used for soil stabilization since the 1930's. It appears that some of the crested wheatgrass was established prior to the time the property was obtained by the Army, while other stands have been seeded since that time. Crested wheatgrass communities are relatively stable for a time, but they eventually become senescent and are invaded by other species. It is likely that over a long period (e.g., greater than 100 years), the stands of crested wheatgrass at RMA will deteriorate and be gradually replaced by native species. Several native species presently occur within these stands, but in small numbers.

Sand Sagebrush Shrubland

Sand sagebrush shrubland occurred on sandy upland sites in the southern and southeastern portions of RMA. It was limited in areal extent, covering 100 ha or only 1.5% of RMA. The most conspicuous species in this community type was the sand sagebrush, which totaled 39.5% of the vegetation cover in sand sagebrush shrubland. Dominant herbaceous species included cheatgrass and needle-and-thread, which together contributed another 41.7% relative cover. In many ways, sand sagebrush shrublands were similar to native perennial grasslands or cheatgrass/perennial grasslands, except for the presence of a sagebrush stratum. However, the deeper sands typical of sand sagebrush communities also supported scattered occurrences of prairie sandreed, sand bluestem, and Indian ricegrass. These are native grasses characteristic of sandy areas on the plains.

Forbs provided only 1.5% relative cover in this community type, and cover by bare soil was only 0.8%. Mean height for sand sagebrush was 66 cm. Heights of the dominant grass species ranged between 30 and 49 cm. Mean shrub density in this type was 7,016/ha, with 89.1% provided by sand sagebrush. The high shrub density was in contrast to most of the upland areas at RMA, and it provided a different type of habitat than areas with few shrubs.

Based on species composition and soil characteristics, it is likely that sand sagebrush shrublands were present on RMA prior to settlement. Sandy soils tend to not be good sites for dryland farming, and deeper sands are generally avoided by cattle. However, some grazing probably occurred, which would account for the abundance of cheatgrass in the understory.

Rubber Rabbitbrush Shrubland

Rubber rabbitbrush shrublands occurred as scattered stands on uplands, mostly in the northeastern and southwestern portions of RMA. This type was not as abundant as the sand sagebrush type, covering 24 ha or 0.3% of RMA. In general, it had the appearance of cheatgrass/perennial grasslands with the addition of a rabbitbrush stratum. Rubber rabbitbrush accounted for 25% of the total vegetation cover in this community. Major herbaceous species included cheatgrass, sand dropseed, red three-awn, and bristle thistle. These four herbaceous species accounted for 58.7% of the plant cover. Mean vegetation cover was 73.6%, and cover by bare soil was only 0.4%.

Rubber rabbitbrush were generally taller than sand sagebrush (mean height of 117 cm versus 66 cm). Heights of dominant grasses were similar in the two shrubland types, at 44 cm and 46 cm. Mean shrub density in the rabbitbrush type was 2,550/ha, with rubber rabbitbrush comprising 84.7% of the total.

Yucca Grassland

Yucca communities were mostly limited to the northwestern part of RMA, and to a lesser extent in the south-central part. Yucca grassland covered approximately 58 ha, or 0.8% of RMA. Small soapweed yucca was the most conspicuous and numerically dominant species. Secondary dominants included cheatgrass, needle-and-thread, red three-awn, and sand dropseed. These grass species plus yucca accounted for 87.2% of the total vegetation cover in yucca grassland. In terms of species composition, this community was similar to the cheatgrass/perennial grassland and native perennial grassland types. Mean total vegetation cover was 68.6%, and cover by bare soil and litter was 3.8% and 27.6%, respectively. The high values for total vegetation cover in this type and the two preceding shrubland types result from the abundance of woody species and succulents.

Heights of herbaceous dominants in this type were comparable to those measured in other communities. Mean heights for the dominant grasses ranged from 20 to 36 cm; yucca was taller, with a mean height of 57 cm. Yucca density was 9,680/ha.

The presence of yucca probably is related to soil and topography. In general, yucca grasslands are best developed in areas of coarse but shallow soils, and especially along exposed low ridges. Unless these stands are destroyed by fire or some other disturbance, they probably will persist in their present condition.

Locust Thickets

Dense stands of New Mexico locust occurred primarily in the southern portion of RMA and were almost completely lacking in the northern two-thirds of the site. Most occurrences were of small stands scattered among other upland communities. Locust thickets covered 37 ha or 0.5% of RMA.

Locust probably was planted in association with homesteads on the site before establishment of RMA, or as cover for game at the Rod and Gun Club.

The stands of locust almost always had the tallest stems growing in the centers and the shortest individuals at the margins. This is the result of the species reproducing vegetatively by root sprouts that radiate in all directions from the original individual(s). Fires resulting from human causes or from lightening frequently occur on RMA. Although locust thickets are sometimes destroyed, they quickly regenerate. Cheatgrass was the dominant species in the understory of the locust thickets, along with Kochia and locust sprouts. Together, cheatgrass, Kochia, and locust sprouts accounted for 94.8% of the plant cover in the understory. Total vegetation cover in locust thicket type was 88%, litter 12%, and there was no bare soil. Most of the woody plant density was attributable to locust, which occurred at a density of 5,720 individuals per hectare.

Cottonwood/Willow Stands

Mature plains cottonwoods and peachleaf willows occurred along creeks, irrigation ditches, reservoirs, and in isolated pockets of uplands areas. The stands were mostly limited to the southern part of RMA although a few were present in the northern portion of the site. These trees covered approximately 68 ha, or 1% of RMA. The largest trees reached heights of 90 to 100 ft and frequently formed relatively dense, closed canopy forests. The major species in the understory of these forests included cheatgrass, smooth brome, slender wheatgrass, Canada wildrye, and Kentucky bluegrass. These five grass species accounted for 82.7% of the total vegetation cover in the cottonwood/willow community. Forbs were minor. Total vegetation cover was 66.4%, and cover by bare soil was only 0.2%, with litter accounting for 34.4% of cover. The grasses in the understory tended to be quite tall; mean heights ranged from 61 to 93 cm. Plains cottonwood occurred at a density of 640/ha (79% of the total density), compared with 120/ha for peachleaf willow. Rocky Mountain juniper was the only other tree species encountered in the samples.

The cottonwood-willow stands represent a stable vegetation type on RMA. They undoubtedly occurred along drainages prior to settlement and have increased as a result of water development. Cottonwoods were also planted for shade around homesteads and various occupied areas of RMA. As long as sufficiently moist areas are present on the site, this type can be expected to persist. However most of the cottonwood willow stands at RMA were composed solely of old individuals. This indicates that successful reproduction has been sporadic, probably being limited to occasional floods which scarify the land and reduce competition of herbaceous plants with cottonwood seedlings.

Bottomland Meadows

Bottomland meadow vegetation occurred at RMA along drainages and irrigation ditches, and to a lesser extent in the drawdown zones adjacent to reservoirs in the southern part of the site. Bottomlands were the most extensive of the wetland areas, covering 190 ha or 2.6% of RMA. Dominant species in these areas were variable, but typically included Canada thistle, prickly lettuce, horseweed, smartweed, and barnyard grass, which combined for 43.2% of the total plant cover in the bottomland meadow type. Additional species included American bulrush, Kentucky bluegrass, showy milkweed, goldenrod, and sweetclover. Under native conditions, the bottomlands probably consisted primarily of western wheatgrass and slender wheatgrass, which occurred in small amounts, along with several species of native perennial forbs. The present composition of the bottomlands at RMA suggests that the current communities have developed since the bottomland areas were disturbed. Total vegetation cover in the bottomlands was 89.2%. This high value is largely the result of ample soil moisture.

The weedy forbs that characterize this type had mean heights of 76 to 103 cm. Heights of grasses ranged from 43 to 72 cm. No shrub species were encountered along the sample transects, although coyote or sandbar willows were present in this type.

The bottomland type most likely occurred on the site prior to settlement, but the current structure and composition is quite different from the meadow-like appearance that would be expected under native conditions. The prevalence of introduced weeds attests to past disturbances. Dominance by Canada thistle will continue and probably increase, since this species is very aggressive and can successfully compete with the perennial grasses that would normally occur as dominants in bottomland sites.

Cattail Marshes

Cattail marshes occurred at the edges of ponds and reservoirs and in overflow areas along streams and ditches. Approximately 55 ha or 0.8% of RMA was marshland. The two major species in this type were broadleaf cattail and narrowleaf cattail. Together, these two species accounted for 91.1% of the vegetation in cattail marshes. Total vegetation cover was 89.9%; there was no bare soil.

Cattail species had a mean height of approximately 175 cm. No shrub species were encountered along the sample transects.

Ornamental Trees and Shrubs

Scattered plantings of ornamental trees and shrubs occurred throughout RMA. Some were the result of plantings around RMA facilities, and others were planted around farm and ranch buildings that pre-dated RMA. The most common ornamental tree species included Siberian elm, green ash, white poplar, and plains cottonwood. Common lilac and matrimony bush were probably the most widely planted ornamental shrubs on the site.

3.3.2 AQUATIC STUDIES

Aquatics field studies were designed to provide qualitative and quantitative information on the water quality and biotic communities of the Lower Lakes (except Upper Derby) at RMA and of an offpost comparison lake (McKay Lake). The major biotic components investigated included phytoplankton, zooplankton, aquatic macrophytes, benthic macroinvertebrates, fish eggs and larvae, adult and juvenile fish, and amphibians. Data on each component except aquatic macrophytes were collected seasonally to identify shifts in community structure. Aquatic macrophytes were sampled only in August, when their areal distribution and diversity are greatest. Sampling periods were late April, mid-May, mid-June, mid-August, and early November of 1987.

Whole water samples were taken during each sampling period and analyzed for standard water quality parameters. The samples were composites of subsamples taken from various depth strata in the upper (inlet) and lower (outlet) ends of the lakes. Subsamples were taken 1 m below the surface, at mid-depth, and 1 m above the bottom. Where the water was less than 2 m deep, only a mid-depth sample was collected. Regardless of depth, three subsamples were taken from each end of each lake. Subsamples were collected using a horizontal Van Dorn-style water bottle, composited in a polyethylene carboy, and thoroughly mixed to ensure homogeneity. The various aliquots taken from the composited samples were placed into appropriate containers and preserved to stabilize the parameters of interest.

Measurements of dissolved oxygen, temperature, pH, specific conductance, and water transparency (Secchi depth) were taken in situ at both the upper and lower ends of the lakes. Additional dissolved oxygen readings were taken within 2 hours of sunset and sunrise to measure the diurnal pulse of dissolved oxygen concentration. The in situ measurements of pH and specific conductance were taken at various depths throughout the water column following the same procedure used for collecting subsamples of whole water. Dissolved oxygen and temperature measurements were taken at intervals of 1 m or less.

Composited whole-water samples were also collected to determine the composition and biomass of the phytoplankton community. Subsamples were collected from the upper and lower ends of each lake, from 1 m below the surface in areas greater than 2 m deep and at mid-depth in shallow areas. Subsamples were composited in a container, and thoroughly mixed before withdrawing three aliquots for analysis.

Two of the three aliquots were preserved with buffered formalin for later analysis of species composition; the third was immediately placed in an ice chest and maintained at 4° C. At the end of the sampling period, each refrigerated sample was thoroughly mixed, and aliquots were spiked with saturated magnesium carbonate solution. These were then passed through glass fiber filters at a vacuum of less than 27 inches of mercury (11 pounds per square inch (psi)) to remove the phytoplankton cells. The filters were folded, placed into glass vials, frozen, and later analyzed for chlorophyll content.

Species identification and enumeration were accomplished using a combination of the Palmer-Maloney method for soft-bodied algae and centric and pennate diatoms, and proportional counting for the identification and enumeration of diatoms following removal of soft tissue. The proportion (i.e., relative abundance) of diatom taxa observed on the slides and the densities calculated for the centric and pennate forms from the Palmer-Maloney analysis together provided a basis for estimating the density of each diatom taxon identified.

The zooplankton community includes microzooplankton (rotifers) and macrozooplankton. Microzooplankton were sampled in the upper and lower ends of each water body using water bottles, as described above for other parameters. In areas less than 2 m deep, three subsamples were taken at mid-depth. In areas greater than 2 m deep, subsamples were taken 1 m below the surface, at mid-depth, and 1 m above bottom. Subsamples from the various depth strata at a location were composited to form the samples for identification and enumeration.

Microzooplankton samples were analyzed using a Sedgwick-Rafter Chamber after being washed with tap water in a 64-micron (u) sieve to remove the formalin. The samples were thoroughly mixed to achieve a homogeneous suspension of organisms, and a portion was then extracted and placed into the counting chamber. The samples were scanned at 100x, and a minimum of 200 organisms (or the number of organisms encountered in five strips) were identified to the lowest practicable level.

Macrozooplankton samples were collected using a 0.5-m diameter plankton net with a 118-u mesh size. Two General Oceanic Model 2030 flowmeters were mounted on the net to measure the volume of water filtered. The organisms collected in the upper and lower ends of each lake were combined to form a single sample. Because of the extensive and dense growths of submergent aquatic plants, tows were mostly limited to the surface strata rather than being done throughout the water column. Samples of both macrozooplankton and microzooplankton were preserved immediately after collection with buffered formalin.

Macrozooplankton samples were analyzed using a Ward Counting Wheel. After the samples were split to achieve a workable density, they were examined at a magnification of 40x, and a minimum of 200 organisms were identified to the lowest practicable level for each analysis.

The benthic macroinvertebrate community was sampled using a Ponar dredge to collect substrate material for quantitative analysis and a dipnet to provide supplemental information where dredge-sampling was not feasible. Samples were taken in the upper and lower ends of each lake and washed across a 590-u mesh screen to remove the sediment prior to being composited. All benthic macroinvertebrate samples were preserved with buffered formalin.

The analytical procedure for macroinvertebrates was similar for dredge and dipnet samples. Rose bengal solution was added to the samples, which were then allowed to stand for 24 to 48 hours to ensure that the organisms absorbed the stain. At the end of this period, the samples were again washed through a 590-u screen, and the brightly colored organisms were picked from the detritus and identified to the lowest practicable level.

Fish

The fish community of each lake was sampled using a variety of gear to capture the species and size ranges present. Adult and juvenile fish populations were sampled by beach seine and a boat-mounted electrofishing unit. Samples of fish eggs and larvae were collected using towed nets and a fry seine.

Beach samples were collected with a 7.6 m x 1.8 m seine constructed of 3.2 mm delta-style netting. Samples were taken at two locations in each waterbody, usually the upper and lower ends, and then composited. Samplers usually waded to a depth of about 1 m, stretched the seine parallel to the shore, and hauled to the shore. A boat was used at Lake Mary because of the steep shoreline.

Electrofishing samples were collected using a 4.9-m (16-ft) boat equipped with a 240-volt, 4000-watt generator coupled to a Coffelt model VVP-15 electrofishing control unit. Current was directed from the control unit to two electrodes positioned about 3 m forward of the boat and two just aft of the working platform. As with the beach seines, samples were collected in both the upper and lower ends of each lake and then composited. Samples consisted of 3-minute electrofishing runs, usually with two individuals netting fish and one operating the boat and electrofishing unit.

All fish collected by beach seine and electrofishing were identified, enumerated, and measured for total length (mm) and weight (g), except when catches were large. Large catches were randomly subsampled and lengths and weights taken on a maximum of 25 individuals of each species. Large fish were processed in the field and returned live to the water. Small fish were preserved in buffered formalin and returned to the laboratory.

Fish eggs and larvae were sampled in open water in the upper and lower ends of each lake using the same techniques as described above for macrozooplankton.

The net used was 5 m long, had a 0.5-m diameter circular mouth, and a 335-u mesh size. The distal end of the net was equipped with a quick-couple plankton bucket screened with a 363-u netting. Samples from the two ends of each lake were composited.

Fry seine samples were taken at the same frequency and using the same method as beach seine samples. The fry seine was 3.0 m x 1.8 m and fabricated of 335-u netting. The distance of each haul varied and was usually dictated by the density and extent of nearshore macrophyte beds. When macrophytes were not a factor, the seine was hauled a distance of about 15 m. All fry seine samples were preserved in buffered formalin.

In the laboratory, fish eggs and larvae were stained with rose bengal solution, and washed with tap water across a 120-u sieve to remove excess stain and preservative. The eggs and larvae were then identified to the lowest practicable level.

Bluegill and largemouth bass were selected for evaluation of condition in the lakes because these were the prevalent species and the ones most frequently caught by fishermen. Condition was defined in terms of weight relative to length using two standard indices: Fulton's condition factor K and weight-length relationships. Condition factor K is a relative index useful for comparing individual fish or, when averaged, for comparing fish populations in different water bodies. Weight-length relationships were calculated from the log-transformed individual weights and lengths of individual fish, using a least squares regression method. Regression lines were compared to evaluate the difference among water bodies.

Qualitative surveys of aquatic macrophytes were performed during the August 1987 sampling period to determine the areal distribution of macrophytes in the lakes and the predominant community constituents. Areal distribution was determined by traversing the lakes by boat and sketching the extent and coverage of the macrophyte beds on large-scale aerial photographs. Specimens of prominent aquatic plants were gathered and identified to compile a list of the aquatic flora.

3.3.3 WILDLIFE STUDIES

This section describes the field methods used for supplementary wildlife investigations at RMA. An effort was made to use widely accepted methods that would provide information on the occurrence, distribution, and relative abundance of selected vertebrate groups on RMA. Studies ranged from detailed quantitative analyses to semiquantitative indices and qualitative observations. More intensive studies were used for species of particular ecological, regulatory, or economic importance, and those considered especially useful as indicators of contamination and habitat quality. Qualitative information was collected to provide a comprehensive view of ecosystem structure and function, and to corroborate the major patterns evidenced by the quantitative investigations. Detailed methods are provide in the Wildlife Study Technical Plan (MKE, 1985).

The following subsections describe field methods employed for terrestrial vertebrates at the RMA and the offsite comparison areas.

Studies of deer and rabbits involved a combination of road transects, fecal pellet transects, and opportunistic sightings. For deer, systematic road routes were driven on RMA. An offpost comparison route was driven near Horse Creek Reservoir in an area recommended by CDOW. Distribution and relative habitat use by deer at RMA were also investigated by counting fecal pellet groups at 111 plots. The plots had been originally used for quantitative studies of nesting songbirds and were uniformly distributed across RMA. Studies of rabbit distribution and abundance at RMA were conducted concurrently with road transects and fecal pellet transects for deer. Offpost comparison areas for rabbits were at Buckley ANG.

Coyotes, foxes, and other carnivores are not readily surveyed using visual counts. Therefore, studies of these species relied upon scent station surveys using an olfactory attractant developed by the USFWS. Scent station surveys were conducted twice at 14 locations during October and November 1986. Each location consisted of five scent stations at 0.3-mile intervals. Information on all large carnivores, such as badgers, relied heavily upon opportunistic observations to supplement scent station data.

Small mammals, which include mice, voles, and ground squirrels, were surveyed primarily by live-trapping in November 1986 and June 1987. Emphasis was placed on documenting species presence and distribution in different habitat types. Trapping in 1986 was conducted at 16 locations onpost and 3 offpost, with a total effort of 3,060 trap-nights. In 1987, the total effort was 1,575 trap-nights. Most of the sampling in 1986 was in major habitat types, while the 1987 sampling focused on minor habitat types. Pocket gophers are not readily sampled by live-trapping. Data on distribution and abundance of these burrowing animals were obtained by counting mounds along the deer and rabbit fecal pellet transects.

Prairie dogs were surveyed in 1986 and 1987 to determine age class composition. In 1986, sampling occurred from 14 to 18 June, with 20 counts conducted on RMA, 4 at Buckley, and 2 at the Plains Conservation Center. In 1987, sampling occurred from 14 to 27 May, with 20 counts again conducted on RMA (at same locations as 1986), 10 counts at Buckley, and 10 at the Plains Conservation Center. Methods used to estimate age-class consisted of observing prairie dogs from a vehicle (using binoculars or spotting scope) and classifying clearly observable animals as either adult or juvenile. Main roads within the three study areas were traveled, and observation points were chosen when at least 30 animals could be seen within 50 m of the vehicle. Age-class estimates were performed after waiting 5 minutes (to let the prairie dogs resume normal activities). Observation points were spaced a minimum of 0.5 mi on RMA; on Buckley and the Plains Conservation Center, observation points were more closely spaced (as close as 0.1 mi) because of the limited extent of prairie dog colonies.

Birds of prey (owls, falcons, hawks, and eagles) were investigated primarily by a combination of road transects and incidental observations on and off of RMA. The offpost transects were in Arapaho and Adams counties, in areas recommended by CDOW. Nest searches were performed at RMA during the 1986 and 1987 breeding seasons. This involved specific searches of areas where results of the spring road transects or opportunistic observations suggested the possibility of a nearby nest.

Ring-necked pheasants and mourning doves were surveyed during the 1986 breeding season by counting territorial/courtship vocalizations at 1-mile intervals along road transects. Counts were made around dawn under favorable weather conditions, with 2 minutes spent at each listening post. Offsite surveys were conducted in areas of Weld County suggested by CDOW. For pheasants, data on male-female ratios were collected along driven routes during February 1986.

Information on the occurrence and abundance of waterfowl, shorebirds, and wading birds at RMA was obtained primarily from systematic surveys during spring and fall migrations. Informal observations during other seasons and a qualitative nesting survey in 1987 also contributed to site-specific data.

Songbird study methods included walked transects in winter 1986, breeding plots in spring/early summer 1986, and unstructured observations throughout the field program. Winter transects were located at 27 sites on RMA and a total of ten sites at Buckley ANG and PCC. Transects generally were 500 m long, except in habitats of limited areal extent. Counts were conducted between dawn and late morning.

Breeding bird surveys were conducted at 111 onpost plots and 54 offpost plots. Breeding plots were 100 m x 100 m (1 ha) in size and were located systematically along road routes. Plots were surveyed by counting all singing males heard within the plot boundaries during a 4-minute period. Each plot was surveyed three times, by three separate observers. Counts were made between dawn and late morning.

Qualitative songbird sightings were made during other field activities. Specific searches of minor habitats (especially wooded areas) were also done to document use by less common species. Searches were made during all four seasons.

Most of the observations pertaining to amphibians and reptiles were incidental to other field programs. Information recorded included vocalizations and visual sightings to determine species occurrence, distribution, and relative abundance. In addition, spring surveys of permanent and ephemeral water bodies for breeding anurans (frogs and toads) consisted of driving within earshot of wet areas after dusk and noting species heard. Choruses of breeding anurans are readily identifiable to species, and individuals are easily heard over distances of 100 m or more.

4.0 NATURE AND EXTENT OF BIOLOGICAL CONTAMINATION

Contaminants have been detected in the tissues of plants and animals on RMA since the early 1950s. During that period, specific sites of contamination and specific groups of contaminants were identified and examined, usually in relation to selected areas on RMA and limited to particular problems (e.g., bird kills at Basin F). A broader program to assess contaminants in biota from selected locations on RMA and at offpost control sites was established during the late 1970's and continued into the 1980's.

A comprehensive evaluation of all contamination in RMA biota, both onpost and offpost, was initiated in 1985 as part of the biota assessment. This program was designed to determine what, if any, RMA contaminants remained in the environment and constituted hazards to the regional biota. Many of the contaminants known to have been spilled, dumped, or otherwise placed into the RMA environment were toxic: some were known to be persistent, and others were suspected of degrading into other hazardous chemicals (the history of contamination on RMA is provided in Section 1). In order to develop a comprehensive program at an appropriate level of effort, it was first necessary to define what contaminants were of potential concern to biota, and then, by examination of contaminant types and concentrations in abiotic media (e.g., soil, surface water, shallow ground water), determine which of these might still be present in sufficient concentrations, quantities, and locations as to be detected in biota.

This section contains the results of specific sampling programs that were developed to address the current extent of RMA contamination in biota. Although the basic approach was to measure contaminant levels in tissues from specimens collected on RMA and compare them to levels in offpost controls, valuable information was also obtained from samples collected by chance (e.g., raptors found dead on RMA and salvaged for analysis) and from additional samples collected by the USFWS from specific sites on RMA that were unavailable during the current program (e.g., waterfowl samples from

Upper Derby Lake). The results of these analyses are discussed in conjunction with information on known and potential effects on biota and ecosystems in Section 5.0 of this report.

4.1 CONTAMINATION HISTORY

Contaminants have been located in various locations and concentrations on RMA since its creation in 1942. This section contains a summary of the history of the major basins and lakes on RMA, since they are the major sources for contamination of biota. A summary of past mortality and injury to plants and wildlife is also presented here. Historical studies are listed for those interested in additional background on the history of contamination in the wildlife of RMA. In the final part of this section, the contaminant levels found in past studies of RMA wildlife are presented.

A literature review on the Army's use of pesticides and herbicides on RMA was recently prepared by in 1988. The review indicates that substantial quantities of several toxic substances were applied to the RMA environment beginning in the early 1950's, but site-specific information is largely unavailable. This report is contained in Appendix C.

4.1.1 CONTAMINATION HISTORY OF THE BASINS

Basin A, located in a natural depression within Section 36, was the original unlined disposal area for liquids and waste waters resulting from all RMA industrial operations from 1943 to 1956. By 1946, liquid waste leaking through and seeping under the dam on the northwest perimeter of Basin A had ponded in a low area just west of the dam. To drain away the seepage, the Army built a drainage ditch 3,800 ft through a naturally low and swampy area in Section 35 (Basin B) to unlined Basins D and E. Overflows from Basin A then went through Basin B, through open drainage ditches and culverts under C Street, Eighth Avenue, and through the Sand Creek Lateral to Basin D and Basin E. In 1952, the construction of a higher impoundment dike at Basin A took place in anticipation of additional waste to be produced by the CB plant in Section 25. References citing the above actions include USA CWS (1943, 1945a, 1946a, 1946b, 1946c); USA Chemical Corps (1954); Smith (1952, 1953); Thompson (1952, 1953); and Meetze (1952).

The Army built a new unlined Basin C (see Figure 1.1-2) in 1953 in order to accommodate the additional waste produced by full scale production at the GB plant in February 1953. Liquid waste from Basins A and B and from surface drainage in the South Plants all went to the Sand Creek Lateral with the cutoff and bypass of the ditches and culverts mentioned above. Overflows from Basins A and B were therefore diverted into Basin C. Overflows from Basin C first passed to Basin D, then to Basin E (USA Chemical Corps, 1953).

By 1957, Basins A and C were drained into the newly constructed Basin F. Basins B, D, and E were empty by the time of Basin F construction, due to a reduction of liquid waste production from both the Army and SCC operations by 1957. Basins C to E may have been used to store raw process water from overflows in the Lower Lakes during 1957 and 1958 (SCC, 1957 and 1958); Basin C was used as an irrigation water storage reservoir for the wheat rust experimental projects in Sections 23 and 24 (in 1965 or later). After construction of Basin F in 1957, Basin C handled excess water on several occasions betweeen 1957 and 1974. Subsequently, Basins A to E have been relatively dry, with some wetting and/or ponding in wetter months of the year after heavy rains/snows (ESE, 1988, RIC#88243R05).

The near surface contaminants most often found in Basin A are arsenic (as high as 1,100 parts per million (ppm); avg. 20 ppm), mercury (as high as 65 ppm; avg. 0.2 ppm), and the SCC pesticides aldrin, dieldrin, and endrin (maximum of 700 ppm for these contaminants; avg. 10 ppm; ESE, 1988d). Similar contaminants are found in Basin C, but at generally lower concentrations.

Basin F, a 93-ac asphalt-lined surface disposal pond in Section 26, was constructed in 1956 to hold all of the subsequent industrial liquid wastes and wastewaters generated on RMA. Discharges into Basin F ceased in December of 1981. In the spring of 1982, the Army removed the chemical sewer laterals, erected dikes, and built a north-south interceptor ditch to prevent any surface runoff or sewer transported surface drainage from entering Basin F (USA COE, 1981; Black and Veatch, 1981). Liquids commonly covered 40 to 50 % of the surface area of Basin F from 1982 to early 1988, and the remaining surface area remained wet and mushy with water and chemical waste content.

The Army attempted from 1985 to 1988 to reduce the liquid portions of the waste in Basin F with an enhanced evaporation system. In 1988, contaminated liquids were removed to storage tanks and lined holding basins northeast of Basin F, as part of a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) removal action (USA PMO-RMA, 1988). The Army has now encapsulated the contaminated solids, sludges, liner, and sub-liner soils in a waste pile, and covered the basin site with a clay cap (EBASCO, 1988). The one remaining lined holding pond is now covered.

Near surface contaminants found in Basin F in the past included high concentrations of a number of pesticides, metals, solvents, intermediates, and unknown chemical compounds formed in the sludge and liquid in the basin (Asselin and Hildebrand, 1978, RIC#81324R09).

Basin F has been documented as a source of wildlife injury and mortality since 1964 (Reuter, 1964). Large bird kills, especially of waterfowl, were found annually in and about Basin F, possibly since its construction in 1956 (McEwen and DeWeese, 1984, RIC#87091R03). The U.S. Fish and Wildlife Service (USFWS) reported that 291 carcasses of several species of birds were removed from the shoreline of Basin F in just 2 days (May 1 and 2) in 1975 (McEwen and DeWeese, 1984, RIC#87091R03). In an attempt to prevent birds from approaching Basin F, five repeating-fire Zon guns, flashing light pontoons, and six Avalarms were installed around the perimeter fences in 1975; an additional number of devices expanded the system to 12 Avalarms and 12 Zon guns in 1984 (McEwen and DeWeese, 1984, RIC#87091R03). A count of waterfowl mortality at Basin F has been completed quarterly since mid-1981. Mortality counts for 1981 to 1987 are presented in Table 4.1-1. The high counts in 1983 and 1984 were the result of birds that had died in previous years being collected from newly exposed areas of the basin due to low liquid levels. Although scare devices were installed at Basin F, waterfowl mortality figures were still about 200 to 250 individuals per year at that

Table 4.1-1. Annual Waterfowl Mortality at Basin F from 1981 to 1987.

Year	Number of Waterfowl Found Dead
1981	202
1982	222
1983	444*
1984	418*
1985	140
1986	236
1987	139

* Divides half of total for year survey done from June 1983 to June 1984.

Source: Trautmann, 1988.

location during the early 1980's (Thorne, 1983, RIC#85115R02). The recent removal of fluids from Basin F and placement of a clay cap on the area should substantially reduce or eliminate waterfowl mortality due to Basin F.

4.1.2 HISTORY OF THE LOWER LAKES

As early as 1951, mortality of waterfowl and aquatic organisms led to the suspicion that organic chemicals from Hyman (now SCC) facilities in the South Plants were leaking back into the Lower Lakes via return water canals. An estimated 20,000 ducks died in the years 1949-1959 in the Lower Lakes; this was considered a minimum estimate at the time (Finley, 1959). Waterfowl were particularly vulnerable to pesticides in the Lower Lakes during the years in which chemical production was being pursued in the South Plants. Waterfowl losses associated with contaminated sites on RMA ranged from 2,000 to 3,000 individuals annually throughout the 1950's and early 1960's (USFWS, 1960).

Dead and dying ducks and ducks exhibiting abnormal behavior as a result of chemical contamination (presumably from RMA sources) have been observed on Upper Derby, Lower Derby, and Ladora Lakes on RMA. Studies by the USFWS have shown that resident ducks were the hardest hit by contamination. Ducks were observed to die of convulsions, fly with noticeable loss of equilibrium, and in several instances fly at full speed into the sides of buildings (USFWS, 1952). One mallard, which died while showing characteristic signs of lethal organochlorine contamination at Lower Derby Lake, had 1.3 ppm endrin in the brain (USFWS, 1982b). This is above the lethal level of 0.7-0.8 ppm for birds (Stickel et al., 1979a).

The presence of contaminants in the lakes often was deduced from the death of waterfowl. A large duck kill in winter 1951-1952 was attributed to the release of pesticides by Hyman (Kellogg, 1952). The first documentation of pesticides in the lakes was from an SCC analysis that detected dieldrin at 1 ppm and aldrin at 68 ppm in May 1952 (Hyman, 1952). Other chemicals were also introduced into the lakes during this period. A release of caustic in a quantity sufficient to raise the pH of lake water to 10.5 killed all the fish in the lakes in May 1951. In addition, until 1955, Hyman and SCC on various occasions added substantial quantities of muriatic and/or sulfuric acid to the process water to reduce high levels of alkalinity that caused scale to form on heat exchange equipment (Kuzniar, 1951; Meetze, 1951; Hyman, 1954; Culley, 1969).

The caustic and pesticide releases in the 1950's led to a series of expressions of concern by the Army about the entry of chemical contaminants into the Lower Lakes (see Armitage, 1951a and 1951b; Kellog, 1951a, 1951b, 1952; Smith, 1951). The Army commissioned studies of contamination of the Lower Lakes in the latter 1950's. Pesticide levels were found to remain persistently high in wildlife (Jensen, 1955, RIC#84292R04), and waterfowl mortality continued to be high throughout the rest of the Lower Lakes system in the remainder of the 1950's (Finley, 1959). High waterfowl mortalities continued to be reported in 1961 and 1962 (Sheldon and Mohn 1962). Upon investigation by the Army, it was determined that the contamination was concentrated in the sediments. A sampling program was initiated by the USFWS in 1963 to determine the extent of sediment and wildlife contamination. This program reported up to 2,400 ppm dieldrin in waterfowl fat, up to 14.4 ppm in pheasant fat, while dieldrin in deer fat samples was below detection limits (<0.1 ppm) (Sheldon et al., 1963). SCC also found sediment samples from Upper and Lower Derby Lakes to contain concentrations of up to 183 ppm aldrin, 12.7 ppm dieldrin, 8.3 ppm isodrin, and 10 ppm endrin (SCC, cited in MKE, 1987). The SCC study found the return water ditches to be contaminated with pesticides and residues as well.

In 1964, the U.S. Army removed contaminated sediments from Upper and Lower Derby Lakes and Lake Ladora, as well as the contaminated sediments in the return water canal to Upper Derby. The lakes were refilled in 1965 after sediment removal, and waterfowl mortality in that year declined over that in previous years. In subsequent years waterfowl and other wildlife continued to be found dead at the Lower Lakes but in smaller numbers. Fish also continued to contain levels of contaminants in their tissues after this period, leading to the institution of catch-and-release policies in 1977 and 1978 to prevent human consumption of fish from the Lower Lakes.

Recent analyses of the water in the Lower Lakes confirm that the relatively insoluble pesticide compounds do not lead to detectable values in water samples (Rosenlund et al., 1986). The sediments still contain contaminants, which are in highest concentrations in the upper layers of sediments and near the inlet canals to Lake Ladora and Lower Derby Lake, and are distributed evenly across the upper sediments in Lake Mary (Myers et al., 1983; Myers and Gregg, 1984). Upper Derby Lake has been used only for flood control since 1982, and is often dry. Soil cores from Upper Derby confirm that its sediments continue to be the most highly contaminated in the Lower Lakes (EBASCO, 1988). Further detail on these recent studies is presented in Section 4.3.3.1.

4.1.3 HISTORICAL CONTAMINATION LEVELS IN WILDLIFE

A substantial body of information on the presence and distribution of contaminants in RMA biota exists as a result of past investigations conducted since the mid-1950's. Several of these investigations have documented i[illegible]ants and several species of wildlife levels of several contaminants that represent potential risk to humans and biota. Table 1.3-1 summarizes documented wildlife deaths and injuries on RMA, while Tables 4.1-2 thru 4.1-6 summarize concentrations in wildlife and plants. It can be seen that contaminants occur in varying concentrations in all classes of wildlife, from invertebrates to birds and mammals. The historical levels and effects of these contaminats will be discussed in the following section.

Red-tailed hawks were found dead in Section 36 with high levels of dieldrin, endrin, dichlorodiphenylethane (DDE), and polychlorinated biphenyl (PCB) in 1982 (USFWS, 1983). Dead coyotes, owls, and hawks found at scattered locations on RMA (from 1976 to 1981) had significant concentrations of pesticides in their tissues.

Most data indicating contamination in the tissues of plants and animals at RMA are associated with identified major sources of known or potential contamination. Contaminants data from biota in the Lower Lakes are presented in Table 4.1-2; from biota in Section 36 in Table 4.1-3; from biota in Section 24 (including North Bog) in Table 4.1-4; from biota in Section 26 (including Basin F) in Table 4.1-5; and from Sections 6, 7, 11, 12, 19, 23, 30 and 35 in Table 4.1-6. Due to the quantity of existing information, ranges of contamination in species are presented and reference is made to pertinent documents as sources of additional information.

Table 4.1-2. Contaminants Recorded From Biota From the Lower Lakes (Lake Mary, Lake Ladora, Lower Derby, and Upper Derby) (Page 1 of 4)

Section	Species Represented	Contaminant	Amount Range ppm ppm (parts per million)	Reference
01	Algae	Aldrin	3.0 - 73.0	Finley 1959; USFWS 1962; Peterson & Finley, 1962
02	Algae	Aldrin	1.2	USWFS, 1962
01	Blue-winged Teal	Aldrin	0.1 - 0.17	McNeill 1981a
01	Mallard	Aldrin	0.03 - 0.20	McNeill, 1978; 1981a; 1982
01	Aquatic snails	Aldrin	9.0 -38.0	USFWS, 1962
01	Redhead	Aldrin	1.0	USFWS, 1962
01	Black Bullhead	Aldrin	0.03 - 0.28	USA, 1981
02	Black Bullhead	Aldrin	0.01	USFWS, 1975
02	Leech	Aldrin	0.1	USFWS, 1965
02	Bluegill	Aldrin	0.01	USFWS, 1975
01	Largemouth Bass	Aldrin	0.03	USA DPC, 1975a
02	Largemouth Bass	Aldrin	0.08 - 0.1	USA DPC, 1975a
02	Rainbow Trout	Aldrin	0.18	USA, 1977
02	Mourning Dove	Aldrin	0.05	McNeill, 1981a
02	Largemouth Bass	Arsenic	2.0 - 2.20	USA, 1981
02	Northern Shoveler	Chlordane	15.0	McEwen, 1981
02	Mallard	Chlordane	4.8 - 20.0	McEwen, 1981
02	Mallard	CPM Sulfoxide	0.25 - 0.26	Thorne, 1980
02	Mallard	CPM Sulfide	0.04	Thorne, 1980
02	Mourning Dove	CPM Sulfone	0.22	McNeill, 1982
01	Mallard	Copper	16.8 - 31.5	McNeill, 1978
02	Mallard	Copper	8.6 - 9.4	McNeill, 1978
01	Blue-winged Teal	DBCP	0.36	McNeill, 1981a
01	Mallard	DBCP	0.03 - 0.51	McNeill, 1981a
01	Algae	Dieldrin	2.7 - 45.0	USFWS, 1962; Peterson & Finley, 1962
02	Algae	Dieldrin	23.0 - 39.0	USFWS, 1962; Peterson & Finley, 1962
01	Tiger Salamander	Dieldrin	117.0	USFWS, 1962
01	Northern Pintail	Dieldrin	5.0 - 36.0	USFWS, 1962; Peterson & Finley, 1962
02	Northern Pintail	Dieldrin	5.0 - 36.0	McEwen, 1981
02	Northern Shoveler	Dieldrin	10.0 - 44.0	Finley, 1959; USFWS, 1962; McEwen, 1981
02	Green-winged Teal	Dieldrin	9.0 - 58.0	Finley, 1959; USFWS, 1962; McEwen, 1981
01	Blue-winged Teal	Dieldrin	0.12 - 39.0	USFWS, 1962; McNeill, 1981a; Thorne, 1980
02	Blue-winged Teal	Dieldrin	39.0	McEwen, 1981
01	Mallard	Dieldrin	0.52 - 48.0	USFWS, 1962; McNeill, 1981a; McNeill, 1978;
02	Mallard	Dieldrin	0.08 - 81.0	McNeill, 1982; USA, 1982 McNeill, 1978; USA, 1982 McNeill, 1982; USA, 1982 USA DPC, 1973; USA, 1982

Table 4.1-2. Contaminants Recorded From Biota From the Lower Lakes (Lake Mary, Lake Ladora, Lower Derby, and Upper Derby) (Continued, Page 2 of 4)

Section	Species Represented	Contaminant	Amount Range ppm (parts per million)	Reference
01	Gadwall	Dieldrin	3.4	Paterson & Finley, 1962
01	Aquatic snails	Dieldrin	32.0 - 77.0	
02	Aquatic snails	Dieldrin	22.0 - 28.0	McEwen, 1981
01	Redhead	Dieldrin	12.0	USFWS, 1962
02	Redhead	Dieldrin	10.0	USFWS, 1962
01	Ring-necked Duck	Dieldrin	4.0	USFWS, 1962
01	Canada Goose	Dieldrin	2.1 - 3.0	McEwen, 1981
02	Goldeneye	Dieldrin	8.8	McEwen, 1981
01	Northern Pike	Dieldrin	0.03 - 0.17	USA, 1981; USA, 1982; Berry, 1984; USA, 1984; McNeill, 1981
02	Northern Pike	Dieldrin	0.03 - 0.12	USA, 1982; Berry, 1984; USA, 1984; McNeill, 1981
01	American Coot	Dieldrin	1.43 - 5.0	McEwen, 1981; USA DPG, 1973
02	Channel Catfish	Dieldrin	0.16 - 0.22	USA, 1981; USA, 1982; Berry, 1984; USA, 1984
01	Black Bullhead	Dieldrin	0.05 - 0.44	USA, 1981; USA, 1982; Berry, 1984; USA, 1984; McNeill, 1984
02	Black Bullhead	Dieldrin	0.03 - 0.40	USA, 1981; USA, 1982; Berry, 1984; USA, 1984; McNeill, 1984
02	Leech	Dieldrin	83.0	McEwen, 1981
02	Bluegill	Dieldrin	0.03 - 3.05	USFWS, 1975; USA, 1981; USA DPG, 1975b; USA, 1982; Berry, 1984; USA, 1984
01	Common Merganser	Dieldrin	6.6	McEwen, 1981
02	Common Merganser	Dieldrin	6.6 - 14.0	McEwen, 1981
01	Largemouth Bass	Dieldrin	0.03 - 0.46	USA, 1981; USA, 1982; McNeill, 1981b
02	Largemouth Bass	Dieldrin	0.03 - 3.94	USFWS, 1975; USA, 1981; USA, 1982; USA DPG, 1975b; Berry, 1984; McNeill, 1981
01	Pheasant	Dieldrin	0.04 - 0.16	McNeill, 1982
02	Pheasant	Dieldrin	0.04 - 14.4	McEwen, 1981; Thorne, 1980
02	Rainbow Trout	Dieldrin	2.0	USA, 1977
01	Desert Cottontail	Dieldrin	0.03 - 0.59	McNeill, 1982; Thorne, 1980; USA, 1982; Berry, 1984; USA, 1984
02	American Robin	Dieldrin	2.3	Finley, 1959
02	Cattails	Dieldrin	5.0	USFWS, 1962
02	Mourning Dove	Dieldrin	0.03 - 0.61	McNeill, 1981; McNeill, 1982; Berry, 1984; USA; 1984
01	Blue-winged Teal	Endrin	0.1 - 0.11	McNeill, 1981
01	Mallard	Endrin	0.04 - 0.18	McNeill, 1981a; McNeill, 1982
02	Mallard	Endrin	0.03 - 0.24	McNeill, 1978; McNeill, 1982
01	Northern Pike	Endrin	0.03 - 0.04	USA, 1981; USA, 1982; McNeill, 1981b
02	Channel Catfish	Endrin	0.03	USA, 1982
01	Black Bullhead	Endrin	0.03 - 0.14	USA, 1981; USA, 1982; McNeill, 1981b

Table 4.1-2. Contaminants Recorded From Biota From the Lower Lakes (Lake Mary, Lake Ladora, Lower Derby, and Upper Derby) (Continued, Page 3 of 4)

Section	Species Represented	Contaminant	Amount Range ppm (parts per million)	Reference
02	Black Bullhead	Endrin	0.03	USA, 1981; USA, 1982
01	Bluegill	Endrin	0.03	USA, 1981
01	Largemouth Bass	Endrin	0.03 - 0.04	USA, 1981; USA, 1982
01	Aquatic snails	Endrin	1.41	Thorne et al., 1979
02	Aquatic snails	Endrin	1.41	Thorne et al., 1979
02	Rainbow Trout	Endrin	0.29	USA, 1977
02	Mourning Dove	Endrin	0.03 - 0.42	McNeill, 1981a; 1982
02	Rainbow Trout	Heptachlor epoxide	0.01	USA, 1977
01	Mallard	Isodrin	0.13	McNeill, 1978
01	Black Bullhead	Isodrin	0.02 - 0.03	USA, 1981
02	Mourning Dove	Isodrin	0.13 - 0.16	McNeill, 1981a
01	Blue-winged Teal	Mercury	2.1 - 5.3	McNeill, 1981a
01	Mallard	Mercury	0.29 - 3.8	McNeill, 1981a
01	Northern Pike	Mercury	0.28 - 1.60	USA, 1981; USA, 1982; Berry, 1984; USA, 1984; McNeill, 1981b
02	Northern Pike	Mercury	0.21 - 4.5	USA, 1982; Berry, 1984; USA, 1984, McNeill, 1981b
02	Channel Catfish	Mercury	0.35 - 0.50	USA, 1981; Berry, 1984; USA, 1984
01	Black Bullhead	Mercury	0.16 - 9.0	USA, 1981; USA, 1982; Berry, 1984; USA, 1984; McNeill, 1981b
02	Black Bullhead	Mercury	0.20 - 0.94	USA, 1981; USA, 1982; Berry, 1984; USA, 1984; McNeill, 1981b
01	Bluegill	Mercury	0.36	USA, 1981
02	Bluegill	Mercury	0.14 - 1.80	USA, 1981; USA, 1982; Berry, 1984; USA, 1984
01	Largemouth Bass	Mercury	0.40 - 0.44	USA, 1981; USA, 1982; McNeill, 1981b
02	Largemouth Bass	Mercury	0.19 - 15.3	USA, 1981; Berry, 1984; USA, 1984; McNeill, 1981b
01	Pheasant	Mercury	0.23 - 1.2	McNeill, 1982
01	Desert Cottontail	Mercury	0.2	McNeill, 1982
02	Northern Shoveler	P,p-DDE	0.1 -1.8	McEwen, 1981
01	Blue-winged Teal	P,p-DDE	0.07	McNeill, 1981a
01	Mallard	P,p-DDE	0.23 - 0.47	McNeill, 1978
02	Mallard	P,p-DDE	0.1 - 0.39	McNeill, 1978; McNeill, 1982
02	Aquatic snails	P,p-[illegible]	1.0	McEwen, 1981
01	Canada Goose	P,p-DDE	0.04 - 7.0	McEwen, 1981
02	Goldeneye	P,p-DDE	1.4	McEwen, 1981
01	Northern Pike	P,p-DDE	0.03 - 0.21	Berry, 1984; USA, 1984; USA, 1982
02	Northern Pike	P,p-DDE	0.03 - 0.14	USA, 1982; Berry, 1984; USA, 1984; McNeill, 1981b
02	Channel Catfish	P,p-DDE	0.05 - 0.09	USA, 1982; Berry, 1984; USA, 1984

Table 4.1-2. Contaminants Recorded From Biota From the Lower Lakes (Lake Mary, Lake Ladora, Lower Derby, and Upper Derby) (Continued, Page 4 of 4)

Section	Species Represented	Contaminant	Amount Range ppm (parts per million)	Reference
01	Black Bullhead	P,p-DDE	0.03 - 0.12	USA, 1981; USA, 1982; Berry, 1984; USA, 1984; McNeill, 1981b
02	Black Bullhead	P,p-DDE	0.03 - 0.43	USFWS, 1975; USA, 1982; Berry, 1984; USA, 1984; MCNeill, 1981b
02	Leech	P,p-DDE	4.5	McEwen, 1981
01	Bluegill	P,p-DDE	0.37	USA, 1981
02	Bluegill	P,p-DDE	0.03 - 0.10	USFWS, 1975; USA, 1982; Berry, 1984
01	Common Merganser	P,p-DDE	1.4	McEwen, 1981
02	Common Merganser	P,p-DDE	1.3	McEwen, 1981
01	Largemouth Bass	P,p-DDE	0.05 - 0.08	USA, 1982; McNeill, 1981b
02	Largemouth Bass	P,p-DDE	0.03 - 0.30	USFWS, 1975; McNeill, 1978
02	Pheasant	P,p-DDE	0.03 - 1.4	McEwen, 1981; Thorne, 1980
02	Rainbow Trout	P,p-DDE	0.23	USA, 1977
02	Mourning Dove	P,p-DDE	0.02 - 0.53	McNeill, 1981a; Berry, 1984; USA, 1984
01	Blue-winged Teal	P,p-DDT	0.19	McNeill, 1981a
01	Mallard	P,p-DDT	0.02 - 0.96	McNeill, 1981a; 1978; 1982
02	Mallard	P,p-DDT	0.03 - 0.10	McNeill, 1978; 1982
02	Aquatic snails	P,p-DDT	0.1	USFWS, 1965
01	Northern Pike	P,p-DDT	0.04 - 0.09	USA, 1982; Berry, 1984; USA, 1984
02	Northern Pike	P,p-DDT	0.03 - 0.09	Berry, 1984; USA, 1984
01	Black Bullhead	P,p-DDT	0.02 - 0.04	USA, 1981
02	Black Bullhead	P,p-DDT	0.03 - 0.11	USFWS, 1975; USA, 1982; Berry, 1984; USA, 1984
02	Leech	P,p-DDT	0.7	USFWS, 1965
02	Bluegill	P,p-DDT	0.01 - 0.03	USFWS, 1975; Berry, 1984; USA, 1984
01	Largemouth Bass	P,p-DDT	0.07 - 0.1	USA, 1981; USA, 1982
02	Largemouth Bass	P,p-DDT	0.02 - 0.09	USA, 1982
02	Mourning Dove	P,p-DDT	0.08	McNeill, 1981a
02	Rainbow Trout	Parathion	0.30	USA, 1981; 1982

Table 4.1-3 Contaminants Recorded From Biota in Section 36 (Page 1 of 2)

Species Represented	Contaminants	Amount Range ppm (parts per million)	Reference
Prairie Dog	Oxathiane	0.12	Thorne et al., 1979
Earthworms	Aldrin	0.02	Thorne et al., 1979
Grasshoppers	Aldrin	0.705	Thorne et al., 1979
Earthworms	Cadmium	3.63	Thorne et al., 1979
Prairie Dog	CPM Sulfone	0.12 - 0.22	Thorne et al., 1979
Grasshoppers	CPM Sulfone	0.11 - 0.95	Thorne et al., 1979
Grasshoppers	CPM Sulfoxide	0.27 - 1.11	Thorne et al., 1979
Prairie Dog	Copper	8.50	Thorne et al., 1979
Earthworms	Copper	46.0	Thorne et al., 1979
Grasshoppers	Copper	17.6	Thorne et al., 1979
Deer Mouse	Copper	5.30	Thorne et al., 1979
Pheasant	Copper	8.10	Thorne et al., 1979
Western Meadowlark	Copper	25.3	Thorne et al., 1979
Desert Cottontail	Copper	14.1	Thorne et al., 1979
Mourning Dove	Copper	6.3	Thorne et al., 1979
Prairie Dog	Dieldrin	0.04 - 0.57	Thorne et al., 1979
Earthworms	Dieldrin	6.57	Thorne et al., 1979
Grasshoppers	Dieldrin	0.078 - 1.38	Thorne et al., 1979
Deer Mouse	Dieldrin	0.02 - 0.49	Thorne et al., 1979
Pheasant	Dieldrin	0.2	Thorne et al., 1979
Western Meadowlark	Dieldrin	0.99	Thorne et al., 1979
Desert Cottontail	Dieldrin	0.21	Thorne et al., 1979
Mourning Dove	Dieldrin	0.53 - 1.81	Thorne et al., 1979, Thorne, 1980

Table 4.1-3. Contaminants Recorded From Biota in Section 36 (Continued, Page 2 of 2)

Species Represented	Contaminants	Amount Range ppm (parts per million)	Reference
Prairie Dog	DIMP	0.20 - 1.52	Thorne *et al.*, 1979
Grasshoppers	DIMP	0.17 - 0.71	Thorne *et al.*, 1979
Deer Mouse	DIMP	0.06 - 0.09	Thorne *et al.*, 1979
Prairie Dog	Dithiane	0.13	Thorne *et al.*, 1979
Earthworms	Endrin	0.76	Thorne *et al.*, 1979
Pheasant	Endrin	0.37	Thorne *et al.*, 1979
Mourning Dove	Endrin	0.03 - 0.05	Thorne, 1980
Earthworms	Isodrin	0.02	Thorne *et al.*, 1979
Grasshoppers	Isodrin	0.167	Thorne *et al.*, 1979
Pheasant	Mercury	0.2	Thorne *et al.*, 1979
Western Meadowlark	Mercury	0.33	Thorne *et al.*, 1979
Prairie Dog	P,p-DDE	0.02 - 0.13	Thorne *et al.*, 1979
Grasshoppers	P,p-DDE	0.021 - 0.03	Thorne *et al.*, 1979
Deer Mouse	P,p-DDE	0.02 - 0.05	Thorne *et al.*, 1979
Pheasant	P,p-DDE	0.22	Thorne *et al.*, 1979
Mourning Dove	P,p-DDE	0.04	Thorne *et al.*, 1979
Earthworms	P,p-DDT	0.18	Thorne *et al.*, 1979
Pheasant	P,p-DDT	0.11	Thorne *et al.*, 1979
Mourning Dove	P,p-DDT	0.05	Thorne, 1980

Table 4.1-4. Contaminants From Biota in Section 24 (Page 1 of 2)

Species Represented	Contaminants	Amount Range ppm (parts per million)	Reference
Mallard	Oxathiane	0.20	Thorne, 1980
Aquatic snails	Oxathiane	0.36	Thorne et al., 1979
Mallard	Aldrin	0.02	McNeill, 1982
Aquatic snails	Aldrin	0.03 - 0.33	Thorne et al., 1979
Mourning Dove	Aldrin	0.04 - 0.05	McNeill, 1981a
Earthworms	Cadmium	2.45	Thorne et al., 1979
Mallard	CPM Sulfoxide	0.20 - 0.24	Thorne, 1980
Mourning Dove	CPM Sulfide	0.2	McNeill, 1981a
Aquatic snails	Copper	13.4	Thorne et al., 1979
Earthworms	Copper	2.6	Thorne et al., 1979
Deer Mouse	Copper	5.50	Thorne et al., 1979
Pheasant	Copper	12.9	Thorne et al., 1979
Meadowlark	Copper	25.9	Thorne et al., 1979
Mourning Dove	Copper	18.5	Thorne et al., 1979
Canadian Thistle	Copper	3.0 - 120.0	USA, 1983
Musk Thistle	Copper	5.0 - 9.0	USA, 1983
Cheatgrass	Copper	5.0 - 8.0	USA, 1983
Pheasant	DBCP	0.03	McNeill, 1981a
Cheatgrass	Dieldrin	0.06	USA, 1983
Kochia	Dieldrin	0.09	USA, 1983
Blue-winged Teal	Dieldrin	0.16	USA, 1982
Mallard	Dieldrin	0.08 - 3.58	McNeill, 1981a; 1982; Thorne, 1980; USA, 1982; Berry, 1984, USA, 1984
Aquatic snails	Dieldrin	2.2 - 3.9	Thorne et al., 1979
Earthworms	Dieldrin	1.27	Thorne et al., 1979
Deer Mouse	Dieldrin	0.08	Thorne et al., 1979
Pheasant	Dieldrin	0.04 - 0.15	Thorne et al., 1979; McNeill, 1981a; Thorne, 1980
Meadowlark	Dieldrin	0.05	Thorne et al., 1979
Mourning Dove	Dieldrin	0.02 - 1.23	Thorne et al., 1979, McNeill, 1981a Berry, 1984; USA, 1984
Aquatic snails	DIMP	0.19	Thorne et al., 1979
Cheatgrass	DIMP	0.12 - 6.01	USA, 1983
Musk thistle	DIMP	0.35	USA, 1983
Canadian thistle	DIMP	0.32	USA, 1983
Kochia	DIMP	0.29 - 12.11	USA, 1983
Mallard	Endrin	0.02 - 0.07	McNeill, 1981a; 1982; USA, 1982

Table 4.1-4. Contaminants From Biota in Section 24 (Continued, Page 2 of 2)

Species Represented	Contaminants	Amount Range ppm (parts per million)	Reference
Aquatic snails	Endrin	2.34	Thorne *et al.*, 1979
Earthworms	Endrin	0.84	Thorne *et al.*, 1979
Mourning Dove	Endrin	0.03 - 0.1	Thorne *et al.*, 1979
Cheatgrass	Endrin	0.04	USA, 1983
Aquatic snails	Isodrin	0.05	Thorne *et al.*, 1979
Mourning Dove	Isodrin	0.14	McNeill, 1981a
Mallard	Mercury	0.29 - 2.40	McNeill, 1981a, 1982; Berry, 1984; USA, 1984
Pheasant	Mercury	0.26 - 0.38	Thorne *et al.*, 1979, McNeill, 1981a
Meadowlark	Mercury	0.37	Thorne *et al.*, 1979
Musk thistle	Mercury	0.25 - 0.42	USA, 1983
Mallard	p,p'-DDE	0.09 - 0.16	USA, 1982; Berry, 1984; USA; 1984
Aquatic snails	p,p'-DDE	0.16	Thorne *et al.*, 1979
Earthworms	p,p'-DDE	0.15	Thorne *et al.*, 1979
Deer Mouse	p,p'-DDE	0.05	Thorne *et al.*, 1979
Pheasant	p,p'-DDE	0.04	Thorne *et al.*, 1979
Meadowlark	p,p'-DDE	0.04	Thorne *et al.*, 1979
Mourning Dove	p,p'-DDE	0.03 - 0.15	Thorne *et al.*, 1979; McNeill, 1981a
Canadian thistle	p,p'-DDE	0.17 - 0.22	USA, 1983a
Mallard	p,p'-DDT	0.02 - 0.03	McNeill, 1982; Berry, 1984; USA, 1984
Pheasant	p,p'-DDT	0.07	Thorne, 1980

Addendum: Contaminants Recorded from Biota from the North Bog in Section 24

Species Represented	Contaminants	Amount Range ppm (parts per million)	Reference
Mallard	Dieldrin	0.09 (edible portion)	Thorne, 1986b
	Dieldrin	1.00 (liver)	Thorne, 1986b
	DIMP	0.06 (liver)	Thorne, 1986b
	Endrin	0.07 (liver)	Thorne, 1986b
	p,p'-DDE	0.40 (edible portion)	Thorne, 1986b
	p,p'-DDT	0.08 (liver)	Thorne, 1986b
	1,4-Oxathiane	0.22 (liver)	Thorne, 1986b
Blue-winged Teal	Dieldrin	0.46 (edible portion)	Thorne, 1986b
	Dieldrin	1.3 (liver)	Thorne, 1986b
	p,p'-DDE	0.3 (edible portion)	Thorne, 1986b
	p,p'-DDE	0.08 (liver)	Thorne, 1986b
	Endrin	0.22 (liver)	Thorne, 1986b
	1,4-Oxathiane	0.30 (liver)	Thorne, 1986b

Table 4.1-5. Contaminants Recorded From Biota in Section 26 (Page 1 of 2)

Species Represented	Contaminants	Amount Range ppm (parts per million)	Reference
Northern Pintail	Aldrin	0.00006	USA DPG, 1973
Mallard	Aldrin	0.005	USA DPG, 1973
Earthworms	Aldrin	0.03	Thorne et al., 1979
Grasshoppers	Aldrin	0.169 - 0.39	Thorne et al., 1979
Plains Spadefoot	Aldrin	3-100	USA DPG, 1973
Cheatgrass	Aldrin	0.5 - 0.13	USA, 1983
Rush Skelton weed	Aldrin	0.14	USA, 1983
Earthworms	Cadmium	2.57	Thorne et al., 1979
Cheatgrass	Cadmium	1.0	USA, 1983
Prickly Lettuce	Cadmium	1.0	USA, 1983
Grasshoppers	CPM Sulfoxide	0.36 - 0.51	Thorne et al., 1979
Cheatgrass	CPM Sulfoxide	2.07 - 4.78	USA, 1983
Rush Skelton weed	CPM Sulfoxide	1.48 - 19.5	USA, 1983
Kochia	CPM Sulfoxide	6.00 - 12.12	USA, 1983
Pheasant	CPM Sulfone	0.36 - 1.9	McNeill, 1981a; 1982; USA, 1982; Berry, 1984; USA, 1984
Desert Cottontail	CPM Sulfone	0.27 - 0.46	USA, 1982; Berry, 1984; USA, 1984
Mourning Dove	CPM Sulfone	0.53 - 2.53	USA, 1982; Berry, 1984; USA, 1984
Prickly Lettuce	CPM Sulfide	2.62	USA, 1983
Prickly Lettuce	Copper	5.0 - 9.4	USA, 1983
Prairie Dog	Copper	5.40	Thorne et al., 1979
Earthworms	Copper	31.0	Thorne et al., 1979
Grasshoppers	Copper	7.1 - 37.6	Thorne et al., 1979
Deer Mouse	Copper	6.8	Thorne et al., 1979
Pheasant	Copper	5.70	Thorne et al., 1979
Western Meadowlark	Copper	29.8	Thorne et al., 1979
Desert Cottontail	Copper	13.5	Thorne et al., 1979
Mourning Dove	Copper	14.2	Thorne et al., 1979
Cheatgrass	Copper	5.8 - 15.0	USA, 1983
Kochia	Copper	8.0 - 9.0	USA, 1983
Northern Pintail	Dieldrin	1.3	USA DPG, 1973
Northern Shoveler	Dieldrin	0.340	USA DPG, 1973
Mallard	Dieldrin	0.900	McNeill, 1982; McEwen, 1981; USA DPG, 1973
		0.11 - 0.84	McNeill, 1982; USA DPG, 1973; USA, 1984

Table 4.1-5. Contaminants Recorded From Biota in Section 26 (Continued, Page 2 of 2)

Species Represented	Contaminants	Amount Range (parts per million)	Reference
Earthworms	Dieldrin	7.0	Thorne et al., 1979
Grasshoppers	Dieldrin	0.54 - 5.38	Thorne et al., 1979
Deer Mouse	Dieldrin	4.10	Thorne et al., 1979
Pheasant	Dieldrin	0.02 - 2.83	McNeill, 1981a; 1982; USA, 1982; Berry, 1984, USA, 1984
Plains Spadefoot	Dieldrin	0.0003 - 0.0009	USA DPC, 1973
		2.7	USA DPC, 1973
Western Meadowlark	Dieldrin	2.44	Thorne et al., 1979
Desert Cottontail	Dieldrin	0.04 - 1.87	Thorne et al., 1979, McNeill, 1982 USA, 1982; Berry, 1984; USA, 1984
Mourning Dove	Dieldrin	0.03 - 9.96	Thorne et al., 1979, McNeill, 1982; USA, 1982; Berry, 1984; USA, 1984
Cheatgrass	Dieldrin	0.07 - 0.45	USA, 1983
Rush skeleton weed	Dieldrin	0.48 - 0.57	USA, 1983
Prickly Lettuce	Dieldrin	0.11 - 0.33	USA, 1983
Kochia	Dieldrin	0.24 - 0.33	USA, 1983
Tumble pigweed	Dieldrin	0.58 - 0.63	USA, 1983
Grasshoppers	DIMP	0.17 - 0.36	Thorne et al., 1979
Pheasant	DIMP	0.10 - 1.54	McNeill, 1981a; 1982
Deer Mouse	Dithiane	0.17	Thorne et al., 1979
Earthworms	Endrin	0.98	Thorne et al., 1979
Grasshoppers	Endrin	0.05 - 0.07	Thorne et al., 1979
Pheasant	Endrin	0.03 - 0.32	Thorne et al., 1979, McNeill, 1982; Berry, 1984; USA, 1984
Western Meadowlark	Endrin	0.02	Thorne et al., 1979
Mourning Dove	Endrin	0.09 - 1.21	Thorne et al., 1979, McNeill, 1982; Berry, 1984; USA, 1984
Earthworms	Isodrin	0.32	Thorne et al., 1979
Grasshoppers	Isodrin	0.09	Thorne et al., 1979
Prickly Lettuce	Mercury	0.36	USA, 1983
Mallard	Mercury	0.29 - 1.79	Berry, 1984; USA, 1984
Pheasant	Mercury	0.2 - 0.50	Thorne et al., 1979, Berry, 1984; USA, 1984
Western Meadowlark	Mercury	0.26	Thorne et al., 1979
Desert Cottontail	Mercury	1.56	Berry, 1984; USA, 1984
Cheatgrass	Mercury	0.40	USA, 1983
Mallard	p,p'-DDE	0.05	Berry, 1984; USA, 1984
Pheasant	p,p'-DDE	0.19 - 0.32	Thorne et al., 1979, McNeill, 1981a
Mourning Dove	p,p'-DDE	0.11	Berry, 1984; USA, 1984
Pheasant	p,p'-DDT	0.08 - 0.09	Thorne et al., 1979; McNeill, 1981a

Table 4.1-6. Contaminants in Biota From Sections 6, 7, 11, 12, 19, 23, 30, and 35 (Page 1 of 3)

Section	Species Represented	Contaminant	Amount Range ppm (parts per million)	Reference
06	Pheasant	CPM Sulfone	14.5	McNeill, 1981b
06	Pheasant	Dieldrin	0.02 - 0.54	McNeill, 1981a
06	Pheasant	Endrin	0.02	McNeill, 1982
06	Pheasant	Mercury	0.32	McNeill, 1967
06	Pheasant	p,p'-DDE	0.02	Thorne, 1980
07	Desert Cottontail	Dieldrin	0.04	Thorne, 1980
07	Pheasant	p,p'-DDE	0.27	McNeill, 1981a
07	Pheasant	p,p'-DDT	0.03	McNeill, 1981a
09	Mourning Dove	Aldrin	0.03 - 0.09	McNeill, 1981a; McNeill, 1981b
09	Mourning Dove	CPM Sulfide	0.05 - 1.46	McNeill, 1981a; McNeill, 1981b
09	Mourning Dove	Endrin	0.14 - 0.19	McNeill, 1981a; McNeill, 1981b
09	Mourning Dove	Isodrin	0.02 - 0.14	McNeill, 1981a
09	Mourning Dove	p,p'-DDE	0.04 - 0.62	McNeill, 1981a
09	Mourning Dove	p,p'-DDT	0.04	Thorne, 1980
11	Mallard	Dieldrin	0.03 - 0.57	McNeill, 1982; USA, 1982; Berry, 1984; USA, 1984
11	Mallard	Endrin	0.03	McNeill, 1982
11	Mallard	Mercury	0.22 - 1.0	McNeill, 1982
11	Mallard	p,p'-DDE	0.03	McNeill, 1982
11	Mallard	p,p'-DDT	0.02	McNeill, 1982
12	Blue-winged Teal	Aldrin	0.16	McNeill, 1981a
12	Mallard	Aldrin	0.05	McNeill, 1981a
12	Mourning Dove	Aldrin	0.07	McNeill, 1981a
12	Mourning Dove	CPM Sulfide	0.2	McNeill, 1981a
12	Mallard	Copper	9.6 - 14.4	McNeill, 1978
12	Blue-winged Teal	Dieldrin	0.41	McNeill, 1981a
12	Mallard	Dieldrin	0.06 - 0.97	McNeill, 1978; McNeill, 1981a; McNeill, 1982
12	Mourning Dove	Dieldrin	0.07 - 0.27	McNeill, 1981a
12	Blue-winged Teal	Endrin	0.21	McNeill, 1981a
12	Mallard	Endrin	0.03 - 0.17	McNeill, 1978, McNeill, 1981a; McNeill, 1982
12	Mourning Dove	Endrin	0.1 - 0.2	McNeill, 1981a
12	Mourning Dove	Isodrin	0.11 - 0.22	McNeill, 1981a
12	Blue-winged Teal	Mercury	8.9	McNeill, 1981a
12	Mallard	Mercury	0.51 - 21.8	McNeill, 1981a; McNeill, 1982; Berry, 1984
12	Mourning Dove	p,p'-DDE	0.03 - 0.24	McNeill, 1978, McNeill, 1982; Berry, 1984
12	Blue-winged Teal	p,p'-DDT	0.12	McNeill, 1981a, 1982
12	Mallard	p,p'-DDT	0.02 - 0.03	McNeill, 1982

Table 4.1-6. Contaminants in Biota From Sections 6, 7, 11, 12, 19, 23, 30, and 35 (Continued, Page 2 of 3)

Section	Species Represented	Contaminant	Amount Range (parts per million)	Reference
19	Muskrat	p,p'-DDE	0.15	USFWS, 1962
23	Mourning Dove	Aldrin	0.03	McNeill, 1981a
23	Cheatgrass	Aldrin	0.05	USA, 1983
23	Kochia	Copper	5.0 - 8.0	USA, 1983
23	Prickly Lettuce	Copper	1.0 - 13.0	USA, 1983
23	Canadian thistle	Copper	7.0 - 17.0	USA, 1983
23	Cheatgrass	Copper	1.0 - 11.0	USA, 1983
23	Mourning Dove	CPM Sulfide	0.3	McNeill, 1981a
23	Canadian thistle	CPM Sulfone	1.0 - 2.84	USA, 1983
23	Kochia	CPM Sulfone	1.47 - 2.28	USA, 1983
23	Cheatgrass	CPM Sulfone	2.16 - 3.68	USA, 1983
23	Cheatgrass	CPM Sulfoxide	0.27 - 0.64	USA, 1983
23	Pheasant	DBCP	0.03	McNeill, 1981a
23	Desert Cottontail	Dieldrin	0.05 - 0.06	McNeill, 1982
23	Kochia	Dieldrin	0.22 - 0.28	USA, 1983
23	Canadian Thistle	Dieldrin	0.10 - 0.68	USA, 1983
23	Cheatgrass	Dieldrin	0.04 - 0.08	USA, 1983
23	Canadian Thistle	DIMP	0.50 - 14.88	USA, 1983
23	Mourning Dove	DIMP	0.1	McNeill, 1981a
23	Prickly Lettuce	DIMP	1.88 - 14.64	USA, 1983
23	Cheatgrass	DIMP	0.10 - 0.15	USA, 1983
23	Kochia	DIMP	0.22 - 18.15	USA, 1983
23	Mourning Dove	Endrin	0.2 - 0.25	McNeill, 1981a
23	Mourning Dove	p,p'-DDE	0.13 - 0.24	McNeill, 1981a
23	Canadian Thistle	p,p'-DDE	0.18 - 0.21	USA, 1983
23	Mourning Dove	p,p'-DDT	0.1	McNeill, 1981a
23	Cheatgrass	Mercury	0.24	USA, 1983
30	Pheasant	Dieldrin	0.06	McNeill, 1981a
30	Mourning Dove	Dieldrin	0.17 - 0.51	Berry, 1984
30	Pheasant	Endrin	0.04	McNeill, 1981a
30	Mourning Dove	Endrin	0.02 0.04	Berry, 1984
30	Pheasant	p,p'-DDE	0.08 - 0.10	McNeill, 1981a
35	Mourning Dove	CPM Sulfone	0.22	McNeill, 1982

Table 4.1-6. Contaminants in Biota From Sections 6, 7, 11, 12, 19, 23, 30, and 35 (Continued, Page 3 of 3)

Section	Species Represented	Contaminant	Amount Range (parts per million)	Reference
ND	Lizards/Bullsnakes	Aldrin	0.06 - 0.07	Thorne et al., 1979
		Copper	2.0	Thorne et al., 1979
		Dieldrin	0.06 - 3.78	Thorne et al., 1979
		DIMP	0.31	Thorne et al., 1979
		Endrin	0.12	Thorne et al., 1979
		p,p'-DDT	0.09	Thorne et al., 1979
ND	Beetles/Grasshoppers	Aldrin	0.17 - 0.70	Thorne et al., 1979
		Copper	20.4 - 37/6	Thorne et al., 1979
		Dieldrin	0.08 - 5.38	Thorne et al., 1979
		DIMP	0.17 - 0.71	Thorne et al., 1979
		Dithiane	0.35	Thorne et al., 1979
		Endrin	0.05 - 0.07	Thorne et al., 1979
		Isodrin	0.09 - 0.17	Thorne et al., 1979
		$PCPMSO_2$	0.11 - 2.94	Thorne et al., 1979
		PCPMSO	0.27 - 1.11	Thorne et al., 1979
		p,p'-DDE	0.06 - 0.08	Thorne et al., 1979

ND - Section not designated

Source: ESE, 1988.

Examination of these tables shows that a variety of key wildlife species contain RMA contaminants. Plant tissues have not been examined as thoroughly, but evidence of adverse effects has also been noted. In spite of the fact that a single comprehensive survey had not been conducted, these studies (conducted over a period of more than thirty years) demonstrate that a wide range of species in aquatic, wetland, and terrestrial ecosystems on RMA contain or contained contaminants with known adverse effects on biota.

Numerous studies of contaminant levels in plants, invertebrates, fish, and wildlife have been conducted since the early-1960's (Sheldon and Mohn, 1962; USFWS, 1965, RIC#84296R04; USA DPG, 1973 and 1975a, b, and c, RIC#84296R02, RIC#84296R03, and RIC#85121R07; USA EHA, 1976, RIC#83020R03; Rocky Mountain Fisheries Consultants, 1977, RIC#81286R07; Thorne, 1982, RIC#83042R01; USA WES, 1983; USA, 1984). Studies have also been conducted on some of the chemical contaminants, particularly those that are peculiar to RMA activities, to determine the possible biological effects and concentrations necessary to produce effects (O'Donovan and Woodward, 1977, RIC#81335R08; Guenzi et al., 1979, RIC#81266R04; Palmer et al., 1979, RIC#81266R02; Hart, 1976, RIC#82161R06 and 1980, RIC#82005R02; Thake et al., 1979, RIC#81266R06). Although valuable information was obtained, comparable types of information (e.g., dose levels, physiological effects, toxicity, mutagenicity, effects on reproduction, ability to produce physical abnormalities, etc.) for many suspected compounds of concern are still unavailable.

Comprehensive studies of RMA vegetation included mapping the overall distribution of vegetation types on RMA (Santa Barbara Remote Sensing Institute, 1978a, RIC#81286R08). Color-infrared aerial photography of RMA indicated that plant communities within known areas of contamination (e.g., near Basin F) exhibited stress. Some areas supported vegetation consisting of single stands of weedy species or were bare ground. Twenty-five plant community types and six non-vegetated cover classes were differentiated as a result of these studies.

Subsequent vegetation studies were conducted with the objective of monitoring movements of environmental contaminants on RMA (Santa Barbara Remote Sensing Institute, 1978b, RIC#81286R09). Research focused on three areas: 1) plant community studies, 2) remote sensing studies, and 3) literature surveys on the bioconcentration of RMA contaminants that might serve as biological indicators of contaminated areas. The study resulted in a suggested procedure that was apparently never implemented.

Soil samples from a coring program at RMA were tested for the presence of phytotoxic substances (Torgeson and Sirois, 1976, RIC#81341R02; Cogley et al., 1979, RIC#81266R08). The phytotoxicity data did not indicate the presence of phytotoxic substances except in areas already known to be contaminated on the basis of chemical analyses of the soil samples. Section 36 was extensively contaminated with phytotoxic chemicals generally present over approximately 100 acres. Adjacent portions of Section 35 had two sites showing phytotoxic contamination, and evidence of additional phytotoxicity were encountered in Sections 9, 22, 24, and 26. Toxicants were found primarily in the upper 2 ft of soil where most plant roots are found, occasionally in the horizon from 7 to 12 ft, and rarely below 12 ft.

Several fish species including northern pike, bass, rainbow trout, bullhead, channel catfish, and bluegill from the Lower Lakes on RMA were sampled for contaminants in past studies. Although several compounds were present in detectable levels, the primary chemicals of concern for both fish and waterfowl were the organochlorines associated with pesticide production (Sheldon and Mohn, 1962; USA DPG, 1973, RIC#84131R02; Thorne, 1982, RIC#83042R01). At least a few individuals of all the fish species sampled and all of the waterfowl sampled, including 27 species of ducks found dead or dying on RMA, were found to contain levels of contaminants, primarily the pesticides aldrin and dieldrin, that represent potential risk to humans and biota.

Several additional wildlife species were tested regularly for chemical contamination. The species sampled included cottontail rabbits, ring-necked pheasant, mourning dove, and occasionally mule deer. Control animals were obtained from an area several miles from RMA and were also analyzed for contaminants. Results consistently indicated that higher levels of contaminants were present in the flesh of animals found at selected locations near sites of contamination on RMA than from animals collected from offpost control areas (Thorne, 1982, RIC#83042R01).

The data from other studies conducted at RMA in the past also showed high levels of organochlorines in diverse animals including spadefoot toad, great blue heron, starling, and red-tailed hawk (USA DPG, 1973, RIC#84131R02; USA EHA, 1976, RIC#83020R03; Thorne, 1982, RIC#83042R01). A golden eagle that was shot near the edge of RMA contained 0.15 ppm dieldrin in breast muscle tissue and 1.7 ppm in fat tissue (USFWS, 1982a) . These levels are higher than the median reported in golden eagles by (Reidinger and Crabtree (1974), who determined dieldrin concentrations ranged from <0.1 to 12 ppm (median 0.8) in fat tissue.

The levels of some contaminants (e.g., dieldrin, mercury) in the flesh of game animals and edible fish at RMA exceeded the Food and Drug Administration (FDA) action levels for animal and fish tissue (FDA, 1978, RIC#84338R01). The USFWS expressed concern to the CDH regarding the potential health hazard to humans (USFWS, 1981). Concern was also expressed by the CDOW over the potential movement of pheasants contaminated with pesticide residues off RMA onto private lands on the north and east sides of RMA where they could be hunted. These birds were reportedly contaminated above levels acceptable for human consumption (USFWS, 1981).

Reduced avian reproduction is a well documented effect of organochlorine pesticides and has been documented for one bird species at RMA, the American kestrel. Studies were conducted on kestrels (sparrow hawks) by the Patuxent Wildlife Research Center (USFWS, 1982b). Studies indicated that adverse effects on populations of these birds may have been related to sites of contamination on RMA (see Section 3.2.1 for current studies).

Crude bioassay tests conducted on the aquatic ecosystem of the Lower Lakes indicated that tadpole survival in water from Derby Lake was no different than the survival rate in the control; however, algae from Upper Derby Lake was sufficiently toxic to kill tadpoles within 2 weeks of exposure (Finley, 1959). Other data on bioconcentration of RMA contaminants exist that are consistent with generally known pathways of bioconcentration and bioaccumulation of organochlorine pesticides and other contaminants. However, not much is known about the toxicity and environmental effects of several other RMA contaminants (see Section 5.1.1).

4.2 DEFINITION OF CONTAMINANTS

A list of contaminants of concern to biota was derived by examining all available literature on chemicals found in biota at RMA. This list was augmented by adding compounds found in current screening programs for RMA contamination in soil, surface water, ground water, and air, and compounds known to be associated with past operations at RMA (Geraghty and Miller, 1986, RIC#86107R01). Compounds on the list of potential contaminants of concern to biota that met the selection criteria described in Section 3.2.2.3 were identified as contaminants of concern.

Thirty-nine contaminants were initially identified as contaminants of concern based on this approach. Some contaminants present in abiotic media had been found in previous investigations, but were not included as contaminants of concern to biota unless they were also rated as moderately or highly toxic, or unless their concentrations in biological tissues could be related to some adverse biological effect. Application of the selection criteria indicated that additional considerations were needed in order to correctly identify contaminants of current concern to biota. Additional data on the distribution and concentration of RMA contaminants in physical media were evaluated throughout the biota program in order to keep the list of contaminants of concern to biota current and to evaluate its component chemicals accordingly. One chemical, DIMP, was found to have low environmental toxicity (Dacre and Rosenblatt, 1987), but remained on the list because of its wide distribution in groundwater and because of its degree of concern to regulatory agencies. From the list of 39 contaminants of concern, seven contaminants of major concern were selected as described in Section 3.2.2.3. Further detail on the development and application of this approach is in Section 2.2 of the Task 9 Biota Assessment Final Technical Plan (ESE, 1988d, RIC#88243R05).

Some contaminants from the list of contaminants of concern were combined if review of available information indicated that one chemical was converted to another predominant form in the biological environment, and that its toxicity could be related to that form. A prime example is aldrin, which is converted to dieldrin. The toxic effects of aldrin and dieldrin are additive, and dieldrin is the predominant form in the environment. Contaminants of concern to biota were addressed in the Task 9 Final Technical Plan for Biota studies (Section 2.0) and are discussed in Section 5.0 of this document.

4.3 CURRENT EXTENT OF CONTAMINATION IN BIOTA

4.3.1 PHASE I RESULTS

Evaluation of existing information resulted in the identification of sites and sources of contamination on RMA, development of a list of contaminants of concern to biota, and analysis of preliminary pathways for the movement of contaminants to and through key species and sink food webs.

Information accumulated during the Phase I preliminary assessment has been combined with subsequent data from more detailed studies that were conducted during Phase II and with data from additional studies conducted by MKE. These results follow in Sections 4.0 and 5.0. Results of the Phase I criteria development were used to scope Phase II studies and are presented in Section 2.0 of the Phase II Final Biota Assessment Technical Plan (ESE, 1988d, RIC#88243R05). The Phase I Contamination Assessment focused on obtaining information needed to scope the Phase II sampling program. The information on species, food habits, pathways, etc. has been incorporated into the descriptions of the environmental setting provided in Section 2.0 of this document and in the discussion of contaminant pathways and contaminant effects in Section 5.0.

Major sites and sources of potential contamination identified as a result of Phase I were: South Plants; Lower Lakes; and Basins A, C, D, E, and F. Detailed descriptions of these sites are provided in the appropriate CARs for sites of potential contamination on RMA.

A list of 39 contaminants of concern was developed by screening the available data. Criteria for selecting this list and a discussion of the process are provided in Section 2.2 of the Task 9 Biota Assessment Final Technical Plan (ESE, 1988d, RIC#88243R05), and summarized in Sections 3.2.2.3 and 4.2 of this document.

Preliminary Pathway Analyses were conducted involving initial development of food webs for the three major ecosystems within the defined study area: grassland, wetland, and aquatic. Subsequent analysis of these food webs from a trophic perspective resulted in combining the species into two general webs: aquatic and terrestrial. The species designated as inhabiting the wetland ecosystem could not be logically separated from the trophic structure of either of the other two (e.g., ducks feed on fish, snails, and aquatic vegetation).

Several data gaps identified as a result of Phase I led to the development of a work plan for Phase II investigations. Site characterization data were found to be out of date, studies were needed to provide an adequate biological database to complete an adequate remedial investigation for RMA and the adjacent offpost study area, and additional information was needed on the current distribution of contaminants along pathways in regional food webs. Data that fill these gaps are presented in the remainder of this document.

4.3.2 CONTAMINANTS IN TERRESTRIAL ECOSYSTEMS

Chemical contaminants found in tissues of terrestrial species analyzed under the Phase II program are summarized in Tables 4.3-1 and 4.3-2; a complete list of contaminant analysis results is provided in Appendix D. Following the methodology of the USFWS (DeWeese, 1988, personal communication) mean values are presented only for those instances where more than 50 percent of the samples analyzed indicated the presence of contamination. The detection limit (certified reporting limit) established for each contaminant in each tissue type is presented in Table 4.3-3. In some instances, insufficient sample was available to attain this limit of detection (e.g., brain samples, kestrel eggs, earthworms) within the constraints of the USATHAMA certified method, and the detection limit values were adjusted accordingly to less sensitive levels.

Table 4.3-1. Contaminant Levels in Terrestrial Ecosystems - Terrestrial Program Samples (Page 1 of 2).

Species	Tissue	Location (Section)	Contaminant Level in parts per million (mg/kg wet weight basis)(Range/mean*) Arsenic (n/nt)	Mercury (n/nt)	Aldrin (n/nt)	Dieldrin (n/nt)	Endrin (n/nt)	p,p-DDE (n/nc)	p,p-DDT (n/nc)
TERRESTRIAL PLANTS									
Morning Glory	Whole Plant	RMA, (26, 36)	<0.250-5.35 (1/5)	BDL (5)	BDL (5)	<0.046-0.084 (2/5)	BDL (5)	NRQ	NRQ
	Whole Plant	RMA Control (20)	BDL (1)	BDL (1)	BDL (1)	BDL (1)	BDL (1)	NRQ	NRQ
Sunflower	Flowers	RMA, Basin A	BDL (6)	BDL (6)	BDL (6)	BDL (6)	BDL (6)	NRQ	NRQ
	Flowers	RMA Control (19)	BDL (1)	BDL (1)	BDL (1)	BDL (1)	BDL (1)	NRQ	NRQ
	Leaves	RMA Basin A	<0.250-4.51 (4/5) 1.37	BDL (5)	BDL (5)	BDL (5)	BDL (5)	NRQ	NRQ
		RMA Basin C	BDL (1)	BDL (1)	BDL (1)	>0.300 (1)	0.188 (1)	NRQ	NRQ
	Leaves	RMA (19)	BDL (1)	BDL (1)	BDL (1)	BDL (1)	BDL (1)	NRQ	NRQ
INVERTEBRATES									
Earthworms	Whole	RMA, South Plants	BDL (1)	<0.050->2.35 (1/2)	BDL (1)	1.93 (1)	BDL (1)	BDL (1)	BDL (1)
	Whole	RMA Control (5)	0.618-1.53 (8/8) 1.03	<0.050-0.245 (2/8)	BDL (7)	<0.062-5.30 (1/7)	<0.080-0.914 (1/7)	BDL (8)	BDL (8)
	Whole	Offpost Control	BDL (2)	BDL (2)	BDL (1)	BDL (1)	BDL (1)	BDL (1)	BDL (1)
Grasshoppers	Whole	RMA Section 26	BDL (4)	BDL (4)	0.046-5.8 (4/4) 1.59	0.496-7.2 (4/4) 2.53	<0.064-1.65 (3/4) 0.528	BDL (4)	BDL (4)
		RMA Section 36	0.905-6.60 (4/4) 3.17	<0.050-0.108 (2/4) 0.058	BDL (4)	0.271-0.446 (4/4) 0.381	BDL (4)	BDL (4)	BDL (4)
		RMA Control (7, 8)	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)
		Offpost Control	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)
VERTEBRATES									
Mallard	Juvenile Carcass	RMA***	NRQ	<0.050-0.066 (2/3) 0.051	BDL (3)	<0.031-0.522 (2/3) 0.201	BDL (3)	<0.094-0.507 (1/3)	BDL (3)
	Adult Carcass	RMA	NRQ	BDL (8)	BDL (8)	<0.031-4.53 (3/8)	BDL (8)	BDL-0.360 (4/8) 0.239	BDL (8)
	Juvenile Carcass	Offpost Control	NRQ	BDL (6)	BDL (6)	BDL (6)	BDL (6)	BDL (6)	BDL (6)
	Adult Carcass	Offpost Control	NRQ	<0.050-0.061 (1/8)	BDL (8)	BDL (8)	BDL (8)	<0.094-1.02 (2/8)	BDL (8)
	Egg	RMA (1)	NRQ	0.171-0.185 (2/2) 0.179	BDL (2)	3.0-4.89 (2/2) 3.94	BDL (2)	0.606-0.919 (2/2) 0.762	BDL (2)
	Egg	Offpost Control	NRQ	<0.050-0.186 (5/10) 0.068	BDL (10)	BDL (10)	BDL (10)	<0.094-1.35 (6/10) 0.302	BDL (2)
Ring-necked pheasant	Juvenile Carcass	RMA	<0.250-1.82 (3/11)	BDL (11)	BDL (12)	<0.031-1.33 (5/12)	BDL (12)	BDL (11)	BDL (11)
	Adult Carcass	RMA	BDL (4)	BDL (4)	BDL (4)	<0.031-2.92 (3/4) 0.767	BDL (4)	BDL (3)	BDL (3)
	Juvenile Carcass	Offpost Control	<0.250-1.40 (2/11)	BDL (11)	BDL (14)	<0.031-18.6 (1/14)	BDL (14)	<0.094-1.34 (1/12)	BDL (12)
	Adult Carcass	Offpost Control	BDL (2)	BDL (2)	BDL (3)	BDL (3)	BDL (3)	BDL (2)	BDL (2)
	Egg	RMA	BDL (10)	BDL (11)	BDL (11)	<0.031-5.38 (9/11) 1.12	<0.40-0.143 (1/11)	BDL (10)	BDL (10)
	Muscle**	RMA	<0.250-4.07 (2/20)	BDL (20)	BDL (20)	<0.018-0.063 (2/20)	BDL (20)	BDL (20)	BDL (20)
		Offpost Control	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)

Table 4.3-1. Contaminant Levels in Terrestrial Ecosystems - Terrestrial Program Samples (Continued, Page 2 of 2).

Species	Tissue	Location (Section)	Contaminant Level in parts per million (mg/kg wet weight basis)(Range/Mean*)						
			Arsenic (n/nt)	Mercury (n/nt)	Aldrin (n/nt)	Dieldrin (n/nt)	Endrin (n/nt)	p,p-DDE (n/nt)	p,p-DDT (n/nt)
Ring-necked pheasant	Liver**	RMA	NRQ	NRQ	BDL (6)	<0.018-2.3 (4/6) 0.655	BDL-0.091 (1/6)	BDL-0.44 (1/6)	BDL
		Offpost Control	NRQ	NRQ	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL
	Egg	Offpost Control	BDL (10)	BDL (11)	BDL (11)	BDL (11)	BDL (11)	BDL (10)	BDL (10)
American Kestrel	Juvenile Carcass	RMA	NRQ	BDL (10)	BDL (10)	<0.631-1.01 (5/10) 0.316	BDL (10)	<0.094-0.219 (1/10)	BDL (10)
	Juvenile Carcass	Offpost Control	NRQ	BDL (8)	BDL (8)	BDL (8)	BDL (8)	<0.094-0.733 (1/8)	BDL (8)
	Egg	RMA	NRQ	<0.050-0.405 (8/34)	BDL (33)	<0.031-3.63 (17/33) >0.512	BDL (33)	<0.094-1.25 (1/29)	BDL (29)
	Egg	Offpost Control	NRQ	<0.050-0.057 (1/11)	BDL (11)	BDL (11)	BDL (11)	<0.094-1.04 (2/11)	BDL (11)
Prairie Dog	Carcass	RMA (36) Summer	<0.250-0.741 (2/9)	BDL (9)	BDL (9)	0.233-13.4 (9/9) 2.03	BDL (9)	NRQ	NRQ
	Carcass	RMA (36) Winter	BDL (5)	BDL (5)	BDL (5)	0.119-6.18 (5/5) 1.44	BDL (5)	NRQ	NRQ
	Carcass	RMA, TSY	<0.250-4.22 (1/5)	BDL (5)	BDL (5)	0.064-0.155 (5/5) 0.114	BDL (5)	NRQ	NRQ
	Carcass	RMA Control Summer (19, 20)	BDL (9)	BDL (9)	BDL (9)	<0.031-0.346 (2/9)	BDL (9)	NRQ	NRQ
	Carcass	RMA Control Winter (20)	BDL (5)	BDL (5)	BDL (5)	<0.031-0.096 (1/5)	BDL (5)	NRQ	NRQ
	Carcass	Offpost Control Summer	BDL (9)	BDL (9)	BDL (8)	BDL (8)	BDL (8)	NRQ	NRQ
	Kidneys	RMA, (36) Winter	BDL (5)	<0.10-0.356 (3/5) 0.178	BDL (5)	<0.248-1.54 (2/5)	BDL (5)	NRQ	NRQ
Cottontail	Muscle	RMA, (36)	BDL (7)	BDL (7)	BDL (7)	<0.031-0.092 (3/7)	BDL (7)	NRQ	NRQ
	Muscle	RMA Control (19, 20)	BDL (7)	BDL (7)	BDL (7)	BDL (7)	BDL (7)	NRQ	NRQ
	Muscle	Offpost Control	BDL (7)	BDL (7)	BDL (7)	BDL (7)	BDL (7)	NRQ	NRQ
Mule Deer	Liver	RMA	BDL (14)	BDL (14)	BDL (14)	<0.031-0.187 (1/14)	BDL (14)	NRQ	NRQ
	Liver	Offpost Control	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	NRQ	NRQ
	Muscle	RMA	BDL (14)	BDL (14)	BDL (14)	BDL (14)	BDL (14)	NRQ	NRQ
	Muscle	Offpost Control	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	NRQ	NRQ

* Mean is calculated when 50 percent or more of samples have detectable contaminant levels. If less than 50 percent of samples have detectable contaminant levels, only the range of values are presented. When calculating the mean, values of ½ the detection limit are substituted for samples that are below detection limit.

BDL Below Detection Limit.

n = Number of samples analyzed that contain detectable contaminant levels, nt = total number of samples.

NRQ Not Requested.

** MKE Sample

*** For highly mobile species (mallard, pheasant, kestrel, mule deer) samples were widespread and RMA was evaluated as a whole entity.

Source: ESE, 1988

Table 4.3-2. Contaminant Levels in Terrestrial Ecosystems - Miscellaneous Samples: Samples of Chance and USFWS Supplemental Samples.

Species	Tissue	Location (Section)	Arsenic (n/nt)	Mercury (n/nt)	Aldrin (n/nt)	Dieldrin (n/nt)	Endrin (n/nt)	p,p-DDE (n/nt)	p,p-DDT (n/nt)
			Contaminant Level in parts per million (mg/kg wet weight basis)(Range/Mean*)						
Blue-winged teal	Liver	RMA Upper Derby	BDL (3)	0.371-1.64 (3/3) 1.07	BDL (3)	0.183-0.281 (3/3) 0.239	BDL (3)	BDL (3)	BDL (3)
	Muscle	RMA Upper Derby	BDL (3)	0.259-0.559 (3/3) 0.391	BDL (3)	0.090-0.164 (3/3) 0.127	BDL (3)	BDL (3)	BDL (3)
Redhead	Liver	RMA Upper Derby	BDL (5)	0.080-0.368 (5/5) 0.211	<0.030-0.088 (1/5)	0.307-0.747 (5/5) 0.458	<0.064-0.074(1/5)	<0.094-0.156(1/5)	BDL (5)
	Muscle	RMA Upper Derby	BDL (5)	<0.050-0.073 (2/5)	BDL (5)	0.117-0.326 (5/5) 0.201	BDL (5)	BDL (5)	BDL (5)
American Coot	Liver	RMA Upper Derby	BDL (9)	0.300-1.77 (9/9) 1.08	BDL (9)	<0.124-0.693 (8/9) 0.291	BDL (9)	BDL (9)	BDL (9)
	Muscle	RMA Upper Derby	BDL (9)	<0.050-0.339 (8/9) 0.179	BDL (9)	<0.062-1.77 (8/9) 0.53	BDL (9)	<0.940-0.313 (2/9)	BDL (9)
Mourning Dove	Carcass	RMA (35)	BDL (2)	BDL (2)	<0.633-1.83 (2/2) 1.23	5.57-56.3 (2/2) 30.9	<0.800-3.44 (1/2) 2.0	BDL (2)	BDL (2)
	Liver	RMA (1)	BDL (1)	BDL (1)	BDL (1)	7.37 (1)	3.74 (1)	BDL (1)	BDL (1)
Bald Eagle	Egg	Barr Lake	BDL	0.099	BDL (1)	0.808 (1)	BDL (1)	6.93 (1)	BDL (1)
Golden Eagle	Liver	RMA**	BDL (1)	<0.050-0.216 (1/2) 0.120	BDL (2)	<0.031-0.221 (1/2) 0.118	BDL (2)	BDL (2)	BDL (2)
	Brain	RMA	BDL (2)	<.098-.257 (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)
Ferruginous Hawk	Liver	RMA	BDL (5)	<0.050-0.293 (1/5)	BDL (5)	0.263-4.79 (5/5) 2.66	BDL (5)	BDL (5)	BDL (5)
	Brain	RMA	BDL (5)	<0.050-0.152 (1/5)	BDL (5)	<0.238-9.98 (4/5) 5.07	BDL (5)	BDL (5)	BDL (5)
Red-tailed Hawk	Liver	RMA	BDL (3)	<0.050-0.345 (1/3)	BDL (3)	0.520-6.59 (3/3) 4.10	BDL (3)	<0.313-0.759 (2/3) 0.482	BDL (3)
	Brain	RMA	BDL (3)	<0.050-0.093 (1/3)	BDL (3)	<0.751-9.44 (2/3) 6.36	BDL (3)	BDL (3)	BDL (3)
Great-horned Owl	Liver	RMA	BDL (4)	<0.050-0.086 (2/4) 0.047	BDL (4)	0.143-27.2 (4/4) 11.88	BDL (4)	<0.094-15.5 (3/4) 5.98	BDL (4)
	Brain	RMA	BDL (4)	BDL (4)	BDL (4)	<0.175-15.6 (3/4) 8.80	BDL (4)	<0.529-10.3 (3/4) 3.32	BDL (4)
Northern Harrier	Egg	RMA	BDL (2)	BDL (2)	BDL (2)	0.303-0.676 (2) 0.49	BDL (2)	BDL (2)	BDL (2)
Coyote	Liver	RMA (25)	BDL (1)	BDL (1)	BDL (1)	7.60 (1)	BDL (1)	BDL (1)	BDL (1)
Badger	Liver	RMA (25)	BDL (1)	BDL (1)	BDL (1)	1.64 (1)	BDL (1)	NRQ	NRQ
	Kidneys	RMA (25)	NRQ	NRQ	BDL (1)	0.801 (1)	BDL (1)	NRQ	NRQ

* Mean is calculated when 50 percent or more of samples have detectable contaminant levels. If less than 50 percent of samples have detectable contaminant levels, only the range of values are presented. When calculating the mean, values of ½ the detection limit are substituted for samples that are below detection limit.
BDL Below Detection Limit.
n = Number of samples analyzed that contain detectable contaminant levels, nt = total number of samples.
NRQ Not Requested.
** For highly mobile species (mallard, pheasant, kestrel, mule deer) samples were widespread and RMA was evaluated as a whole entity.
Source: ESE, 1988

Table 4.3-3. Certified Reporting Limits for Biota Analysis Methods

USATHAMA Method Code	Matrix Type	Analyte	Certified Reporting Limit (ug/g)
B-6	Animals and Plants	Arsenic	0.250
C-6	Animals and Plants	Mercury	0.050
D-6	Plants	Aldrin	0.022
		Dieldrin	0.044
		Endrin	0.040
E-6A	Animals	Aldrin	0.020
		Dieldrin	0.031
		Endrin	0.040
F-6A	Animals	p,p'-DDE	0.094
		p,p'-DDT	0.289

Source: ESE, 1988a.

Brief descriptions of contaminant levels in the tissues of each species or group (e.g., earthworms) are provided in the sections that follow. The common and scientific names of all species discussed in this section are listed in Appendix A.

4.3.2.1 Vegetation

Two types of terrestrial plants were collected for contaminant analysis, morning glory and sunflower. These species were selected because of their abundant occurrence in sites of contamination and because they are eaten by important herbivorous species in terrestrial food webs. Morning glories are consumed by prairie dogs and sunflowers are consumed by grasshoppers. The target analytes in terrestrial plants were arsenic, aldrin, dieldrin, endrin, and mercury.

Analysis of six morning glory samples comprised of the entire above ground plant revealed arsenic in a single sample (0.535 ppm), and dieldrin in two samples (0.081 and 0.084 ppm). These three samples were all from Basin A. No other analytes were detected.

Contaminants were detected in five of seven samples comprised of sunflower leaves, but not in the seven samples comprised of flowers. Arsenic was detected in sunflower leaves (4 of 5 samples) from Basin A at concentrations ranging from <0.250 to 4.51 ppm (Mean = 1.37). Dieldrin was detected in plants from Basin C at concentrations exceeding 0.300 ppm, and endrin was detected in plants from Basin C at concentrations of 0.108 ppm. Figure 4.3-1 shows the contaminant levels by location for each species. The ranges and means (as appropriate) of contaminant concentrations are presented in Table 4.3-1.

4.3.2.2 Invertebrates

The two invertebrate groups collected (earthworms and grasshoppers) were analyzed for arsenic, aldrin, dieldrin, endrin, mercury, DDT, and DDE. Contaminant values for earthworms and grasshoppers by location on RMA are presented in Figure 4.3-2.

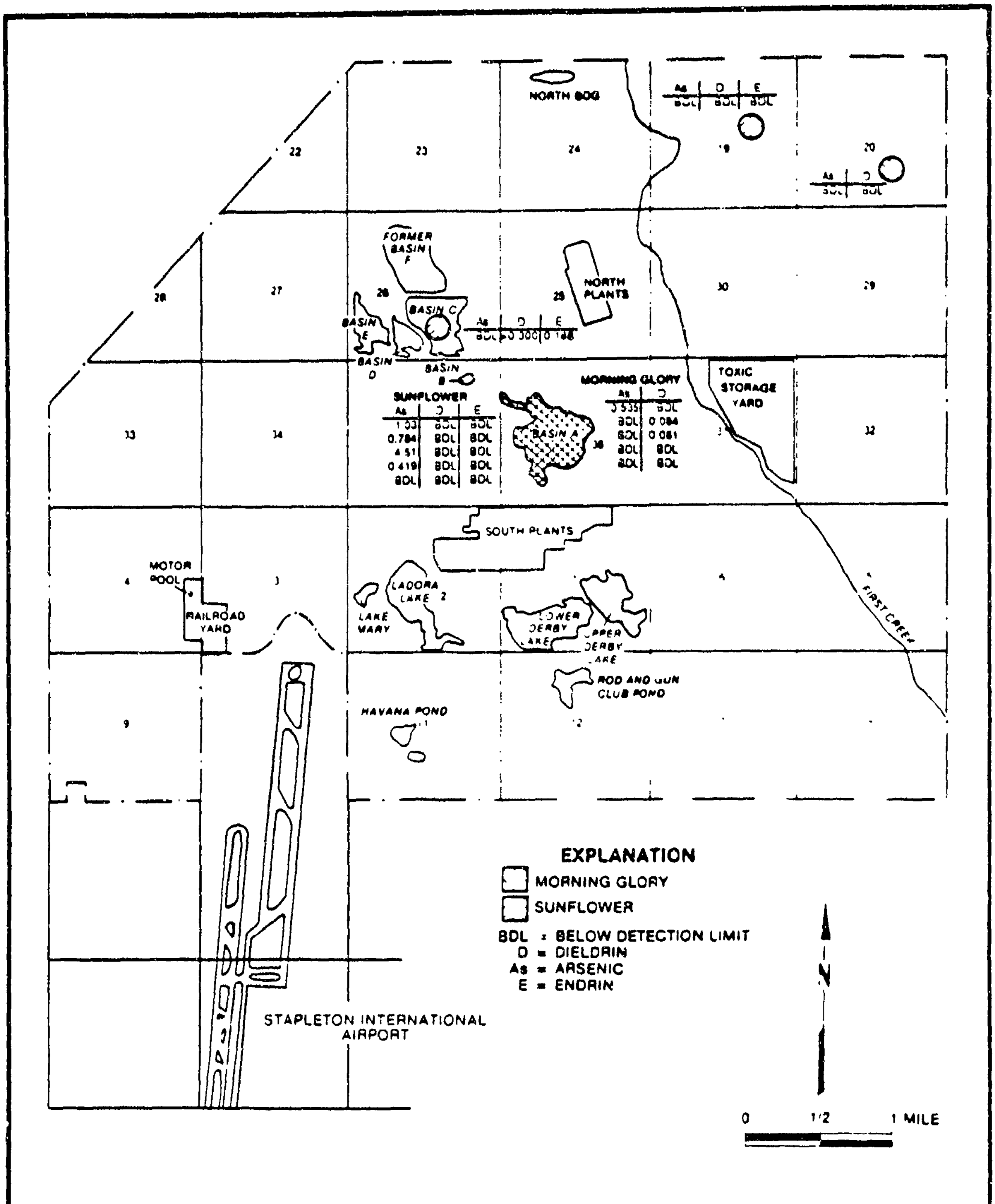

Figure 4.3-1
CONTAMINANT LEVELS IN RMA TERRESTRIAL PLANTS
SOURCE: ESE, 1988

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Aberdeen Proving Ground, Maryland

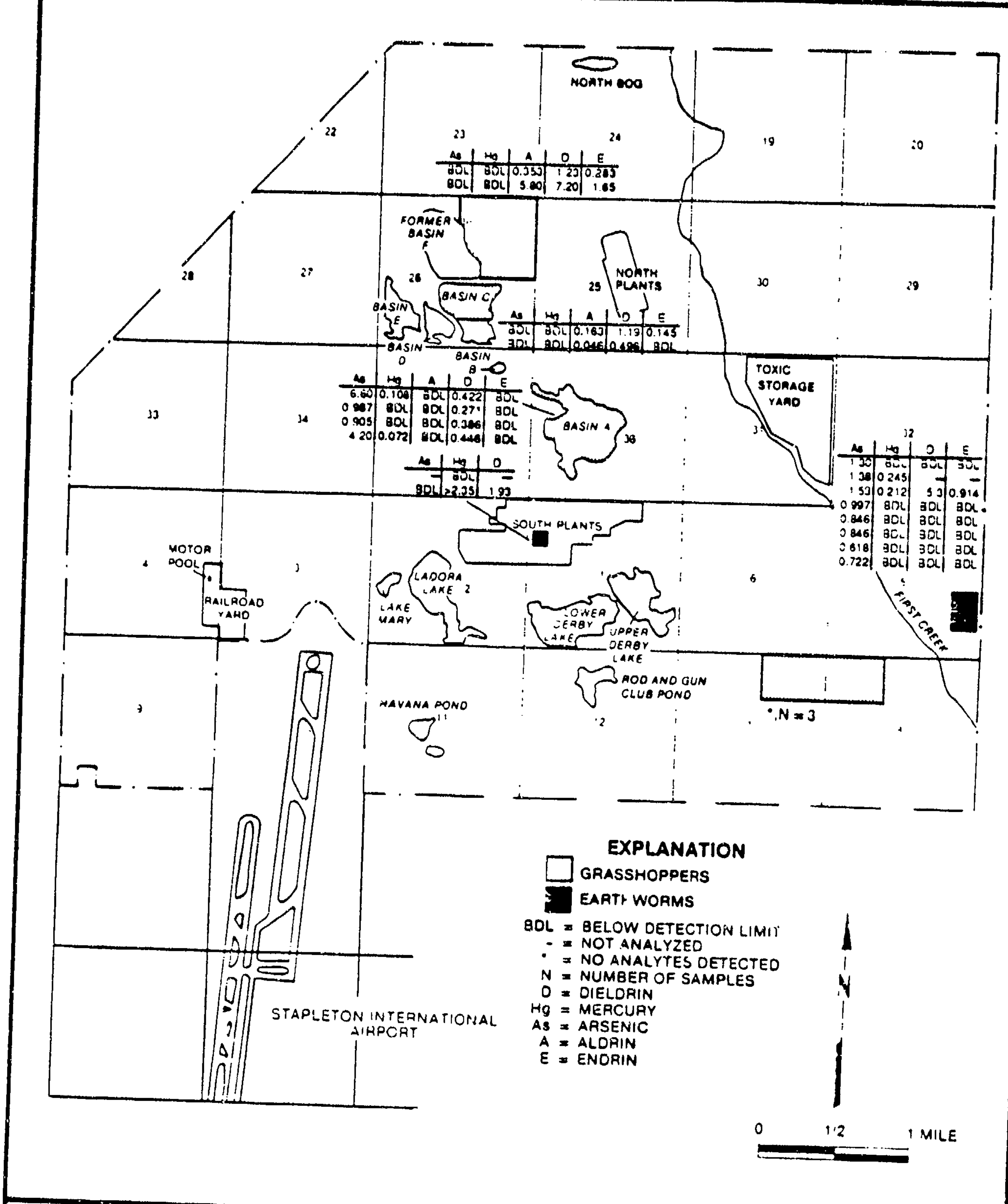

Figure 4.3-2
CONTAMINANT LEVELS IN RMA INVERTEBRATES
SOURCE: ESE, 1988

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Earthworms contained arsenic, dieldrin, endrin, and mercury. DDT, DDE, and aldrin were not detected. Arsenic was observed at concentrations ranging from 0.618 to 1.53 ppm (Mean = 1.03) in all of the eight samples from Section 5 (onpost control). Arsenic was not observed in the sample from the South Plants, RMA (contaminated), or in the two samples from Barr Lake (off-post control). A dieldrin concentration of 1.93 ppm was observed in the single earthworm sample collected from the South Plants, while one of seven samples from the onpost control area had detectable levels (5.3 ppm) of dieldrin.

Endrin was not detected in the sample collected from contaminated sites, but was detected in one of seven samples from onpost controls at 0.914 ppm. Mercury was detected in two of eight earthworm samples from Section 5 at concentrations of 0.216 and 0.245 ppm, and at concentrations of <0.050 and greater than 2.35 ppm in the two earthworm samples from the South Plants. In all offpost control earthworm samples, all analytes were below detection.

Preliminary statistical analysis of earthworm sample data using ANOVA indicated significant differences among the three sites (onpost controls, offpost controls, onpost contaminated). Using Kruskal-Wallis analyses, onpost controls were contrasted with offpost controls, and control samples were pooled and compared to samples from contaminated areas. Of all analytes detected in earthworms, only comparisons for arsenic yielded significant differences. Onpost control samples (Section 5) differed from offpost control samples and pooled control areas differed significantly ($0.05 \geq p > 0.01$) from contaminated sites. Due to the low sample sizes, differences between onpost control and contaminated sites may have remained undetected.

Grasshoppers contained arsenic, aldrin, dieldrin, endrin, and mercury. No DDE or DDT was detected. Arsenic concentrations of 0.905 to 6.6 ppm (Mean = 3.17) were detected in all of the four grasshopper samples from Basin A (Section 36). Aldrin concentrations of 0.046 to 5.8 ppm (Mean = 1.59) were detected in all of the four samples from Section 26. Dieldrin was detected at concentrations of 0.271 to 0.446 ppm (Mean = 0.381) in all four samples from Section 36, and 0.496 to 7.2 ppm (Mean = 2.53) in all four samples from Section 26. Three of four grasshopper samples from Section 26 contained endrin. Concentrations of endrin in the four samples ranged from <0.064 to 1.65 ppm (Mean = 0.528). Mercury was detected only in samples collected from Section 36 (two of four samples). Concentrations for all four samples ranged from <0.050 to 0.108 ppm (Mean = 0.058). Contaminant values by location on RMA are shown in Figure 4.3-2.

In all offpost control grasshopper samples, all analytes were below detection. Further, no contaminants were detected in samples from the northwest corner of Section 8 or the northeast corner of Section 7 (onpost control areas).

Using statistical analysis, grasshopper samples collected in Section 26 were contrasted with those collected from Section 36, onpost controls were contrasted with offpost controls, and pooled data from control sites were contrasted with pooled data from contaminated areas. None of the comparisons for mercury, DDE, and DDT differed significantly. Data on arsenic differed significantly between the two contaminated sites, and approached significance ($0.10 \geq p > 0.05$) for the comparison of pooled control and contaminated sites. Significance was obtained for comparisons of aldrin levels between contaminated sites, but not between pooled contaminated and pooled control sites. Significance was obtained for comparisons of dieldrin levels between contaminated sites, pooled contaminated, and pooled controls, but not between onpost and offpost controls. For endrin, Section 36 values differed significantly from Section 26, but when pooled, these sites did not differ from either onpost or offpost controls.

4.3.2.3 Vertebrates

All vertebrates collected for chemical analysis satisfied the criteria of key species. These criteria are described in Section 3.2.2.2.

Threatened and Endangered Species

The only sample collected from a threatened or endangered species was a single bald eagle egg from the abandoned nest at Barr Lake. The embryo was approximately five days from hatching at the time of abandonment, and exhibited normal development. Residues detected in the egg contents were 0.099 ppm mercury, 0.808 ppm dieldrin, and 6.93 ppm DDE. No arsenic, aldrin, endrin or DDT were detected. Preliminary evaluation of sediment and water data from onpost and offpost surveys and existing knowledge of the feeding habits and foraging range of the Barr Lake eagles do not indicate that the contaminant levels were from RMA sources. A more detailed discussion of effects of RMA contaminants on bald eagles is provided in Section 5.3.

Blood samples were collected by the USFWS from bald eagles roosting on RMA during the winters of 1986-1987 and 1987-1988. These blood samples were sent to Patuxtant Wildlife Research Center to be analyzed for heavy metals and organochlorine pesticide contamination. Based on preliminary results, the eagles roosting on RMA contained very little organochlorine pesticide contamination in the blood. Heavy metals were found in the blood samples collected, but concentration levels were in the range expected for bald eagles (USFWS, 1988).

Raptors

Raptors are conspicuous components of the terrestrial biota on RMA and, as predators at the top of the food chain, are highly susceptible to the effects of bioaccumulation of contaminants. Specimens of five species of raptors from RMA were analyzed. American kestrel eggs and young were collected from onpost and offpost nest boxes as part of the avian reproduction study. Five ferruginous hawks, three red-tailed hawks, four great-horned owls and two golden eagles were found on RMA within one to three days after they had died. These raptors were necropsied and analyzed. The kestrel tissues were analyzed for mercury, aldrin, dieldrin, endrin, DDE, and DDT. Arsenic analysis was not required by the technical plan because arsenic was not expected to bioacummulate in organisms occupying higher levels in the food web. The liver and brain were collected from each of the remaining raptors and analyzed for all of the target analytes.

Dieldrin concentrations detected in the carcasses of six of ten American kestrels collected on RMA ranged from <0.031 to 1.01 ppm (Mean = 0.316). DDE was detected in a single kestrel carcass from RMA at a level of

0.219 ppm. No other analytes were detected in the onpost kestrel samples. The only analyte detected in kestrel carcass samples collected off RMA, DDE had a concentration of 0.733 ppm in a single carcass. Eggs collected from kestrel boxes on RMA had detectable concentrations of mercury (8 of 34 samples), dieldrin (17 of 33 samples), and DDE (1 sample). Contaminant concentrations ranged from <0.050 to 0.405 ppm mercury, from <0.031 to 3.63 ppm (Mean = >0.512) dieldrin, and the single detection of DDE was 1.25 ppm. One of eleven eggs collected offpost contained 0.057 ppm mercury, and two eggs contained 0.837 and 1.04 ppm DDE, respectively; dieldrin was not detected in kestrel eggs collected off RMA. Aldrin, endrin, and DDT were not detected in any kestrel samples. Contaminant values for kestrel eggs and fledglings by RMA location are presented in Figures 4.3-3 and 4.3-4.

Aldrin, endrin, DDE, and DDT did not yield any significant differences for any of the comparisons. For mercury, no significant difference was observed between control and contaminated sites, but differences between eggs and juveniles were significant. In contrast, differences between control and contaminated sites for dieldrin were significant for both juveniles and eggs, while no difference was detected between age groups. Both eggs and juveniles showed higher levels of dieldrin on RMA than offpost; in fact, no dieldrin was detected in either eggs or juveniles offpost.

Ferruginous hawks are currently considered a candidate species by the USFWS and are discussed separately in this paragraph. The brain and liver tissues from several ferruginous hawks found dead on RMA were analyzed for all target analytes. No detectable amounts of arsenic, aldrin, endrin, DDE, or DDT were found in either the liver or brain tissues. Mercury was detected in the liver in one of the five samples analyzed at a concentration of 0.293 ppm. Dieldrin was detected in all five liver tissue samples at concentrations ranging from 0.263 to 4.79 ppm (Mean = 2.66). Contaminants detected in ferruginous hawk brain tissues included 0.152 ppm mercury (one of five samples), and dieldrin in four of five samples. Levels of dieldrin in ferruginous hawk brain tissues ranged from <0.238 to 9.98 ppm (Mean = 5.07). Contaminant values for ferruginous hawk as well as other raptors are shown in Figure 4.3-5 by location on RMA.

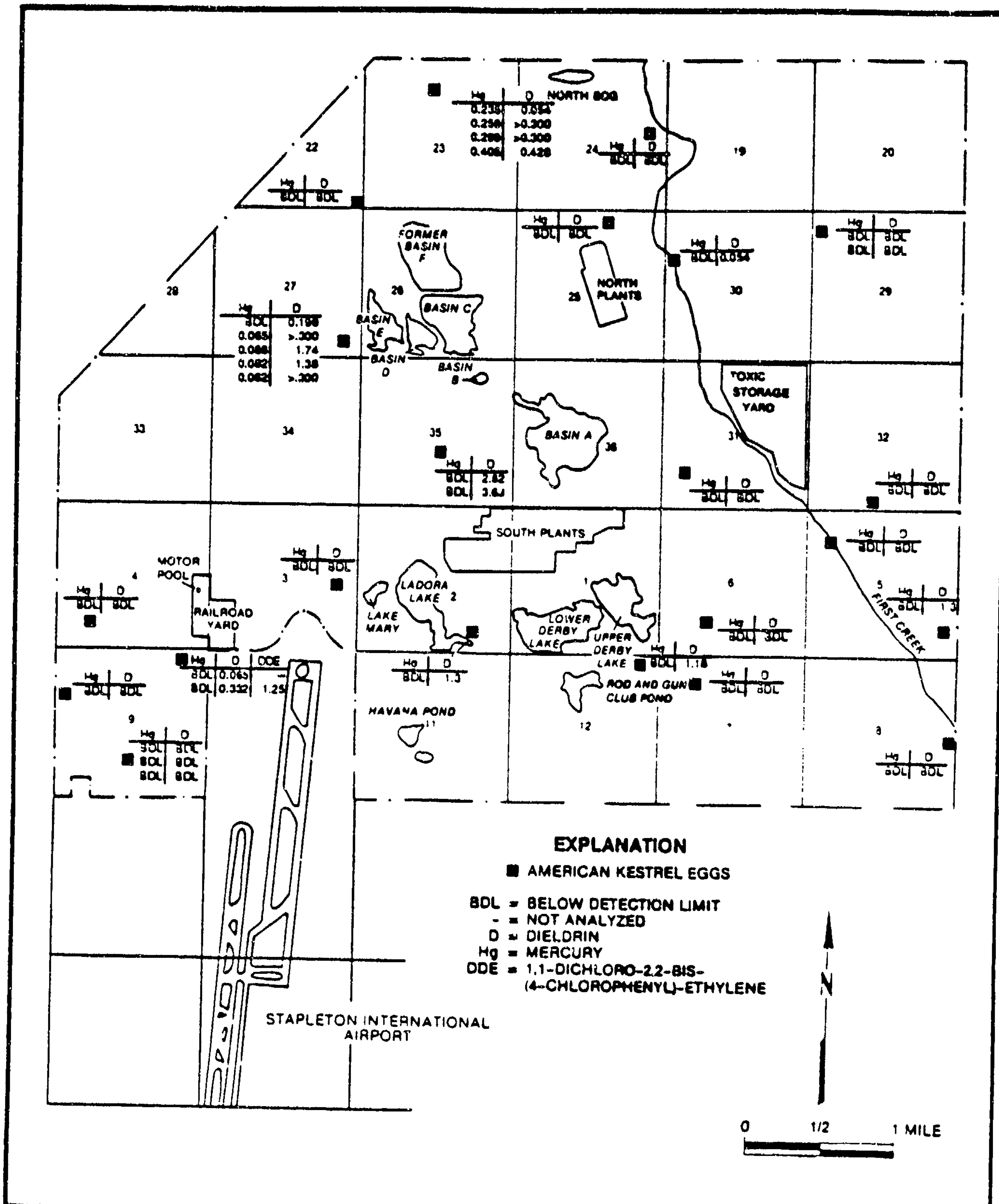

Figure 4.3-3
CONTAMINANT LEVELS IN AMERICAN KESTREL EGGS FROM RMA
SOURCE: ESE, 1988

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Aberdeen Proving Ground, Maryland

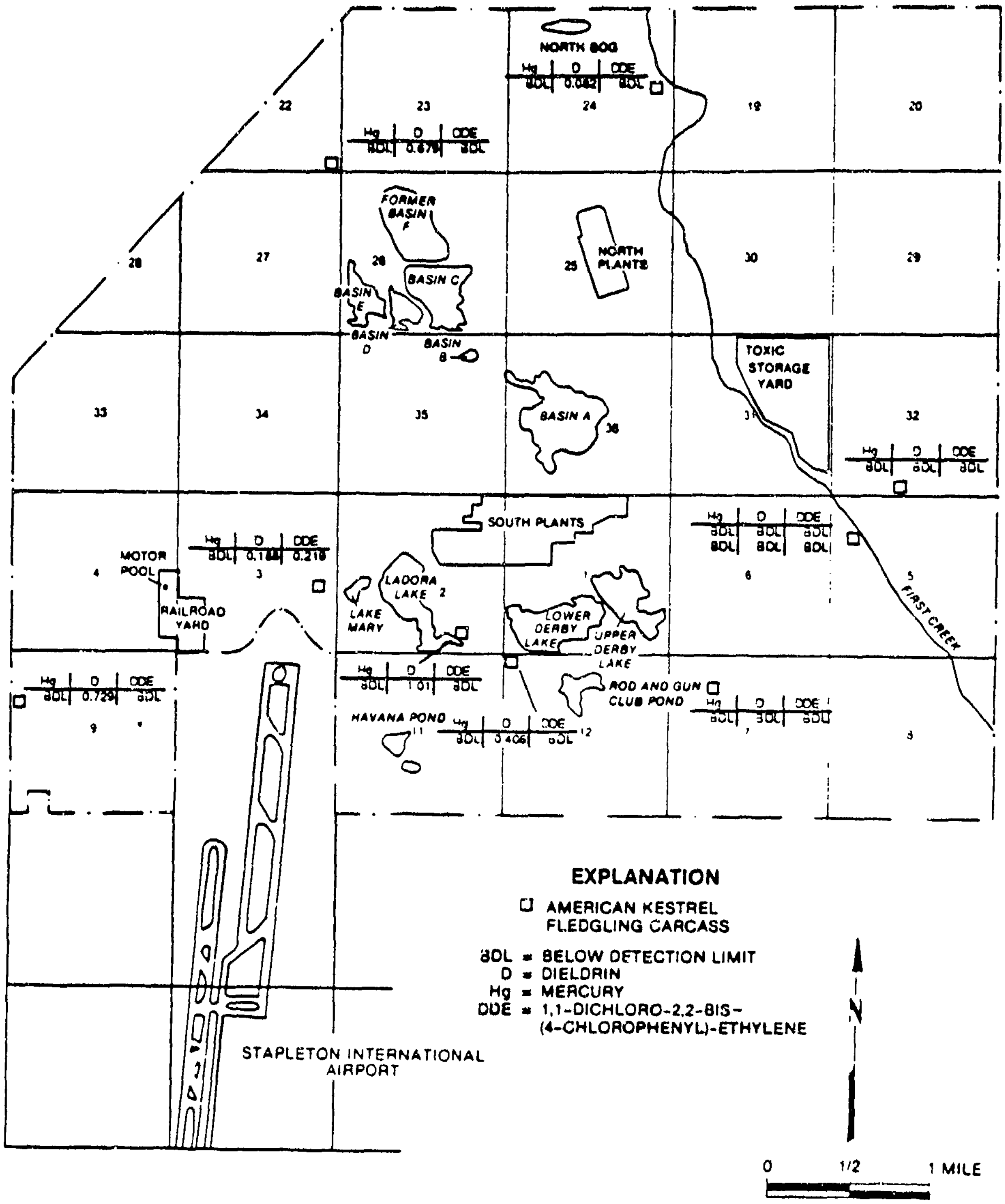

Figure 4.3-4
CONTAMINANT LEVELS IN AMERICAN KESTREL FLEDGLING CARCASSES FROM RMA

SOURCE: ESE, 1988

Prepared for:
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Aberdeen Proving Ground, Maryland

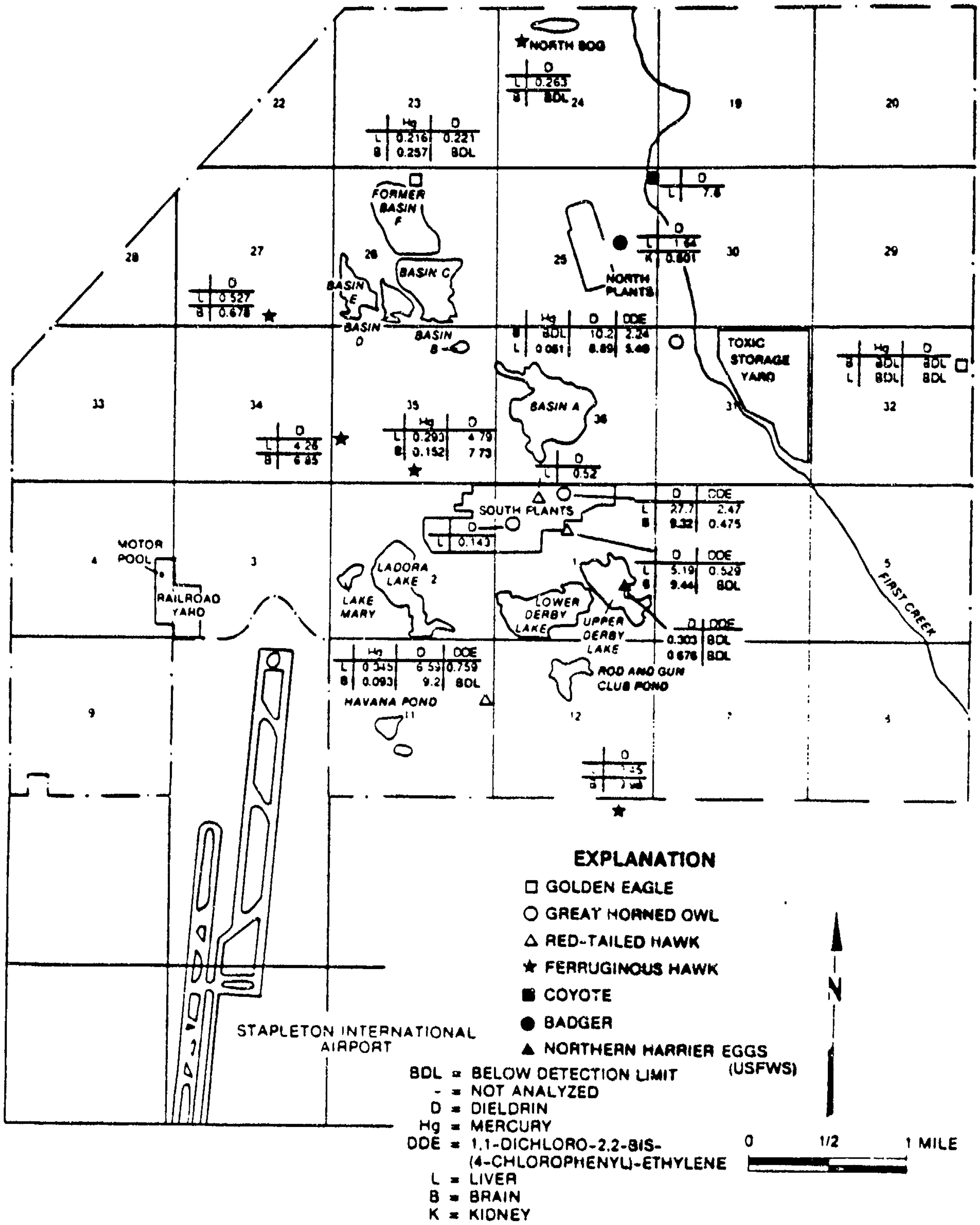

Figure 4.3-5
CONTAMINANT LEVELS IN RAPTORS AND CARNIVORES FROM RMA
SOURCE: ESE, 1988

Prepared for:
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Aberdeen Proving Ground, Maryland

For the remaining raptors, liver and brain tissues were analyzed for all seven target analytes. Combining the data collected from red-tailed hawks, ferruginous hawks, golden eagles and great horned owls provides information on contaminant concentrations in avian species at the top trophic level. Only mercury, dieldrin, and DDE were detected in any of the four species. DDE was detected in the livers of red-tailed hawks and great horned owls, and in the brain tissue of great horned owls. Dieldrin was detected in both the brain and liver tissues of red-tailed hawks, ferruginous hawks, and great horned owls, but only in liver tissue of the two golden eagles. Concentrations of dieldrin and DDE often reached high levels in both liver and brain tissue, with the highest levels generally occurring in great horned owls. Contaminant levels in liver tissue of raptors ranged from <0.050 to 0.345 ppm mercury, <0.031 to 27.7 ppm dieldrin, and <0.094 to 15.5 ppm DDE. The concentration ranges of contaminants in brain tissue for the four species are <0.050 to 0.152 ppm mercury, <0.175 to 15.6 ppm dieldrin, and 0.475 to 10.3 ppm DDE.

Two eggs collected from a northern harrier nest by the USFWS contained dieldrin at levels of 0.303 and 0.676 ppm (Mean = 0.49). No other analytes were detected.

__Mammalian Carnivores__

Two mammalian predators, a coyote and a badger, were found dead (in Section 25 on RMA) and collected for tissue analysis. The coyote contained 7.6 ppm dieldrin in liver tissue. No other target analytes were detected: other tissues were not examined. Tissues analyzed from the badger were liver tissue for arsenic, aldrin, dieldrin, endrin, and mercury; and kidney tissue for aldrin, dieldrin and endrin. The liver contained a dieldrin concentration of 1.64 ppm, and the kidney contained a dieldrin concentration of 0.801 ppm. No other target analytes were detected.

__Game Species__

Important game species collected on RMA for contaminant analysis included waterfowl, ring-necked pheasants, mourning doves, cottontail rabbits, and mule deer. The target analytes in terrestrial game species were arsenic, mercury, aldrin, dieldrin, endrin, DDE, and DDT. The technical plan does not require arsenic analysis for mallard tissue or DDE and DDT analyses for mule deer and cottontail rabbits.

Waterfowl--Waterfowl, including mallards collected by ESE, and redheads, blue-winged teal, and coots collected by the USFWS, were analyzed for contaminants. Mallards were collected on RMA, as well as from control areas offpost, while all the other waterfowl were collected on RMA in the vicinity of the Lower Lakes.

For mallards, the carcasses of juveniles and adults, as well as eggs were analyzed. Mercury, dieldrin, and DDE were detected in both eggs and juveniles collected on RMA, while only dieldrin and DDE were detected in adults collected on RMA. Mercury and DDE were detected in adults and eggs collected offpost, and no target analytes were detected in offpost juveniles. Concentrations of mercury were detected in two of three onpost juvenile mallard carcasses (0.061 and 0.066 ppm) and one of eight offpost adult carcasses (0.061 ppm). Concentrations of dieldrin were detected in two of three onpost juveniles and three of eight onpost adult mallards. No dieldrin was detected in either juveniles or adults collected offpost. Dieldrin concentration in onpost mallards ranged from <0.031 to 0.522 ppm in juveniles, and from <0.031 to 4.53 ppm in adults. DDE in mallards was detected in one of three juvenile carcasses collected onpost, four of eight onpost adult carcasses, two of eight offpost adults, and zero of six offpost juveniles. Detectable DDE concentrations ranged from <0.094 to 0.507 ppm in onpost juvenile carcasses, from below detection limit to 0.360 ppm in onpost adult carcasses, and <0.094 to 1.02 ppm in offpost adult carcasses.

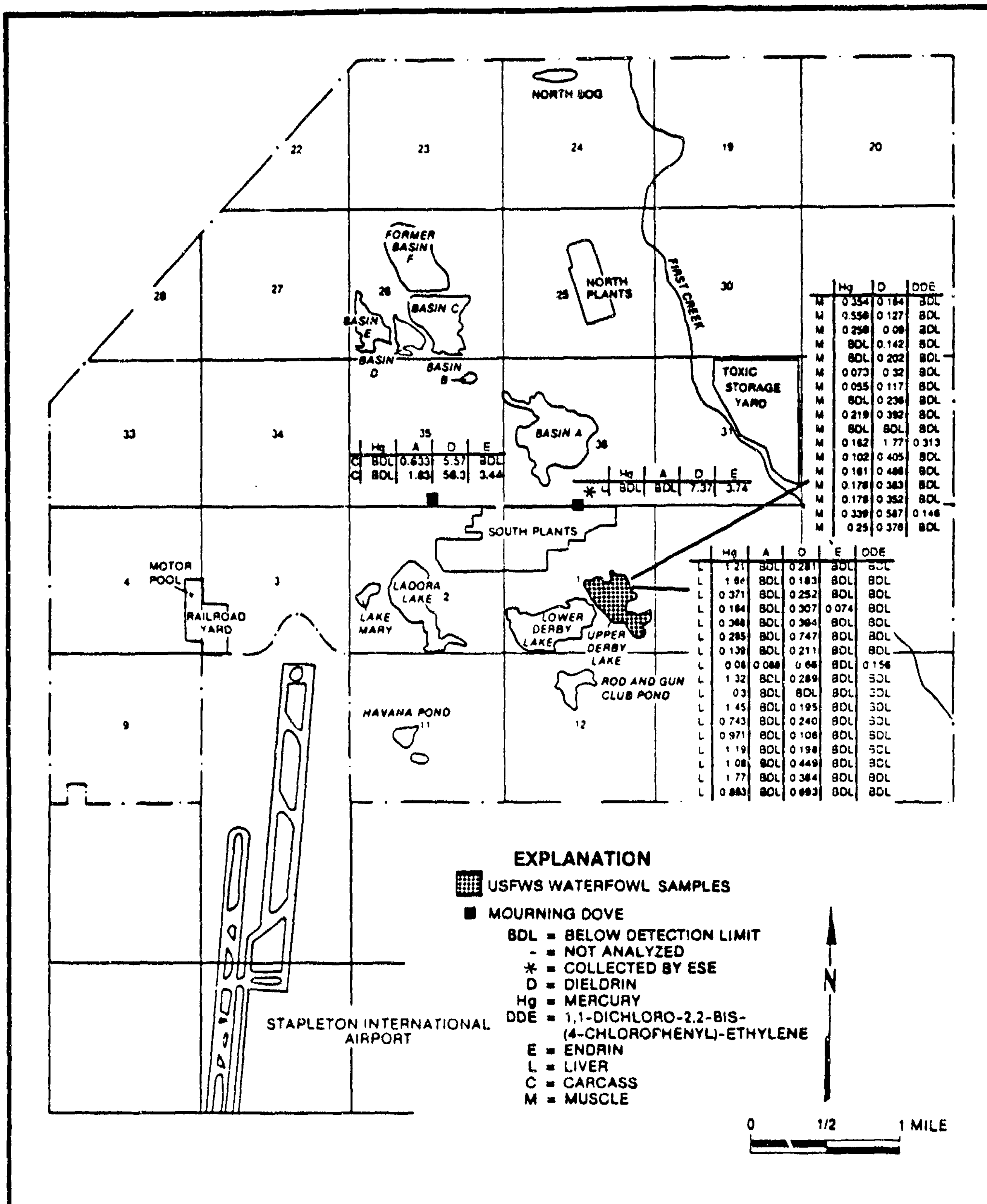
Two mallard eggs collected in Section 1 on RMA contained concentrations of 0.173 and 0.185 ppm (Mean = 0.179; N = 2) mercury, 3.0 and 4.89 ppm (Mean = 3.94; N = 2) dieldrin, and 0.606 and 0.919 ppm (Mean = 0.762; N= 2) DDE.

Contaminants detected in mallard eggs collected off RMA included mercury (range of <0.050 - 0.186 ppm in five of ten samples; Mean = 0.068) and DDE (range of <0.094 - 1.35 ppm in six of ten samples; Mean = 0.302). Offpost mallard eggs contained contaminant concentrations of <0.050 to 0.186 ppm (Mean = 0.068) mercury and <0.094 to 1.35 ppm (Mean = 0.302) DDE. Contaminant levels in mallards are shown for each location in Figure 4.3-6.

Statistical analysis of mallard data contrasted RMA with offpost areas for each type of tissue collected: egg, juvenile carcass, and adult carcass. Differences among age groups when contaminated and control site data were pooled were also analyzed statistically. For mercury, significant differences were found between juveniles from control and contaminated sites, as well as differences among age groups when contaminated and control sites were pooled. For dieldrin, significant differences were identified between control and contaminated sites for eggs ($p<0.001$) and juveniles ($0.05>p>0.01$), and differences approached significance ($0.10>p>0.05$) for adults. Contrasts of pooled contaminated and control sites revealed no differences among age groups for dieldrin. Although none of the statistical tests for DDE revealed significant differences among treatment groups, significance was approached ($0.10>p>0.05$) in the initial comparison of the six groups, as well as in the a priori contrasts of control and contaminated sites for eggs, and the comparison among age groups when sites were combined. Aldrin, endrin, and DDT were not detected in any tissues.

Additional waterfowl samples were collected at Upper Derby Lake on RMA. Mercury concentrations in liver tissue ranged from a low of 0.08 ppm found in a redhead to a high of 1.77 ppm found in an American coot. Dieldrin levels in liver tissue ranged from a low of 0.106 ppm to 0.747 ppm. DDE, aldrin, and endrin were detected in a single liver sample each, at concentrations of 0.156 ppm, 0.088 ppm, and 0.074 ppm, respectively. Muscle tissue analyzed in the three waterfowl species contained levels of mercury, dieldrin and DDE between <0.050 to .559 ppm, <0.062 to 1.77 ppm, and <0.094 to 0.313 ppm, respectively. Contaminant levels in these additional waterfowl are shown by RMA location in Figure 4.3-7.

Ring-necked Pheasant--Juvenile and adult ring-necked pheasants were collected both on and off RMA and analyzed for arsenic, mercury, aldrin,



	Hg	A	D	E
C	BDL	0.633	5.57	BDL
C	BDL	1.83	56.3	3.44

	Hg	A	D	E
* L	BDL	BDL	7.37	3.74

	Hg	D	DDE
M	0.354	0.164	BDL
M	0.558	0.127	BDL
M	0.258	0.08	BDL
M	BDL	0.142	BDL
M	BDL	0.202	BDL
M	0.073	0.32	BDL
M	0.055	0.117	BDL
M	BDL	0.236	BDL
M	0.219	0.392	BDL
M	BDL	BDL	BDL
M	0.162	1.77	0.313
M	0.102	0.405	BDL
M	0.161	0.488	BDL
M	0.176	0.383	BDL
M	0.178	0.352	BDL
M	0.339	0.587	0.146
M	0.25	0.376	BDL

	Hg	A	D	E	DDE
L	1.21	BDL	0.281	BDL	BDL
L	1.64	BDL	0.183	BDL	BDL
L	0.371	BDL	0.252	BDL	BDL
L	0.184	BDL	0.307	0.074	BDL
L	0.364	BDL	0.364	BDL	BDL
L	0.285	BDL	0.747	BDL	BDL
L	0.139	BDL	0.211	BDL	BDL
L	0.08	0.088	0.66	BDL	0.156
L	1.32	BDL	0.289	BDL	BDL
L	0.3	BDL	BDL	BDL	BDL
L	1.45	BDL	0.195	BDL	BDL
L	0.743	BDL	0.240	BDL	BDL
L	0.971	BDL	0.106	BDL	BDL
L	1.19	BDL	0.198	BDL	BDL
L	1.08	BDL	0.449	BDL	BDL
L	1.77	BDL	0.384	BDL	BDL
L	0.883	BDL	0.693	BDL	BDL

Figure 4.3-7
CONTAMINANT LEVELS IN WATERFOWL AND MOURNING DOVES FROM RMA
SOURCE: ESE, 1988

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dieldrin, DDE and DDT. Samples were collected on RMA from interior sections near sources of contamination (Sections 26, 30, 31, 6, and 2 near the Lower Lakes and South Plants) and from perimeter sections (Sections 23, 24, 20, and 8). Juveniles collected on RMA contained detectable levels of arsenic (3 of 11 samples: one each from Sections 23 and 26, and near Lower Derby Lake) and dieldrin (5 of 12 samples) in carcass tissue, while only dieldrin was detected in adult carcasses collected on RMA (3 of 4 samples). All of the samples containing detectable levels of dieldrin came from interior sections of RMA. Arsenic concentrations ranged from <0.250 to 1.82 ppm in juveniles, while dieldrin concentrations ranged from <0.031 to 1.33 ppm in juvenile carcasses, and from <0.031 to 2.92 ppm (Mean = 0.767) in the carcasses of adults collected on RMA. Two juvenile pheasants collected offpost were found to contain concentrations of arsenic (0.72 and 1.4 ppm) and one juvenile pheasant collected from a country club in Larimer County contained 18.6 ppm dieldrin, and 1.34 ppm of DDE. This concentration of dieldrin was the highest detected in any of the pheasants analyzed. No target analytes were detected in the carcass tissues of adults collected offpost. Contaminant values by location for pheasant carcass samples are shown in Figure 4.3-8.

Ring-necked pheasant eggs were collected both on and offpost and analyzed for all seven target analytes. No contaminants were detected in eggs collected off RMA, while most eggs collected on RMA (9 of 11) contained dieldrin. Concentrations of dieldrin ranged from <0.031 to 5.38 ppm (Mean = 1.12). One egg collected on RMA also contained 0.143 ppm endrin. No other target analytes were detected. Contaminant values for RMA pheasant eggs are shown in Figure 4.3-9.

Ring-necked pheasant samples were statistically contrasted by offpost control versus onpost areas, and by age groups (egg, juvenile, or adult). No significant differences in levels of mercury, aldrin, endrin, DDE, or DDT were obtained for any contrasts. No significant differences in levels of arsenic were detected between control and RMA sites within any of the three age groups, but significant differences were revealed among age groups for

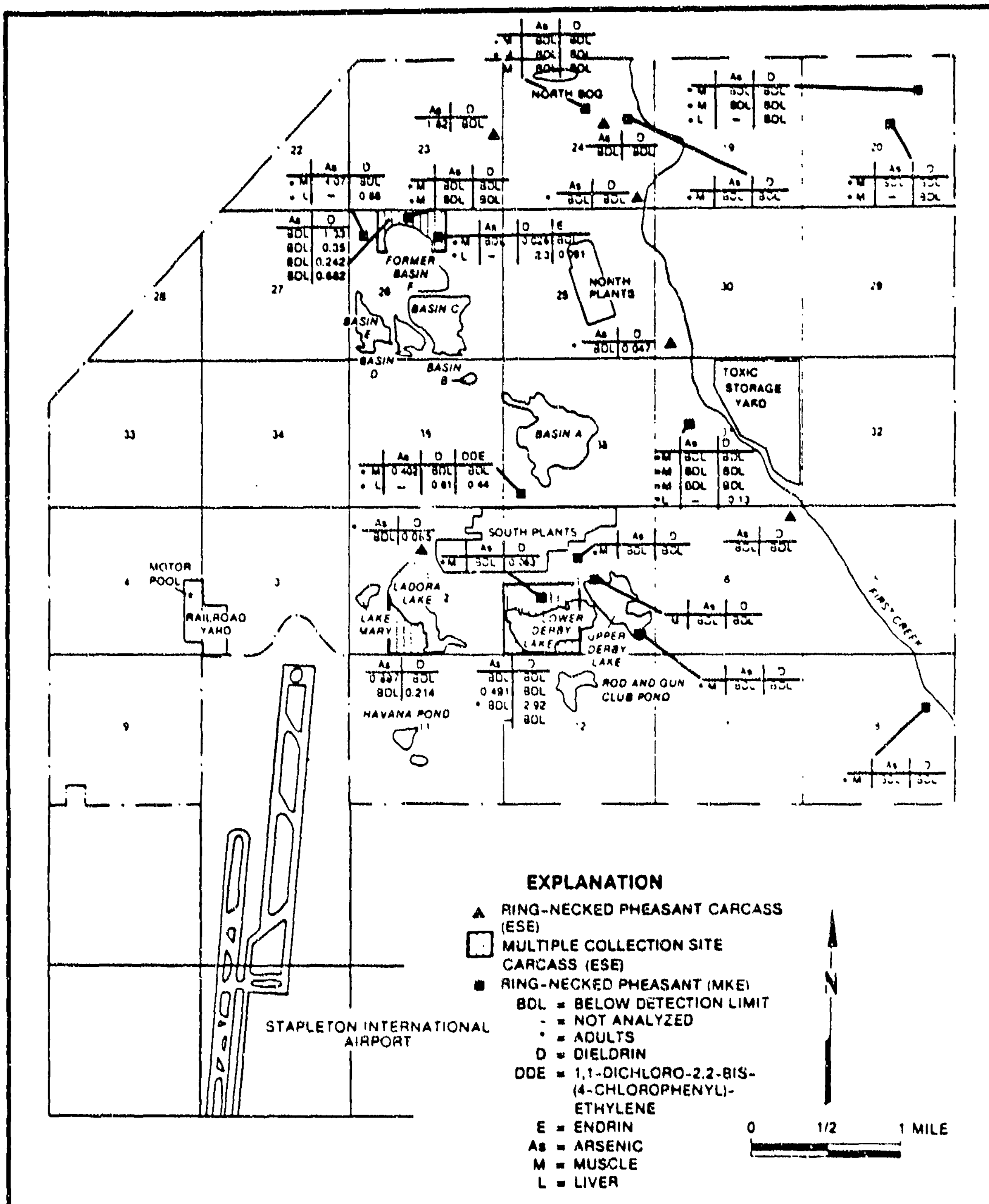

Figure 4.3-8
CONTAMINANT LEVELS IN RING-NECKED PHEASANTS FROM RMA
SOURCE: ESE, 1988

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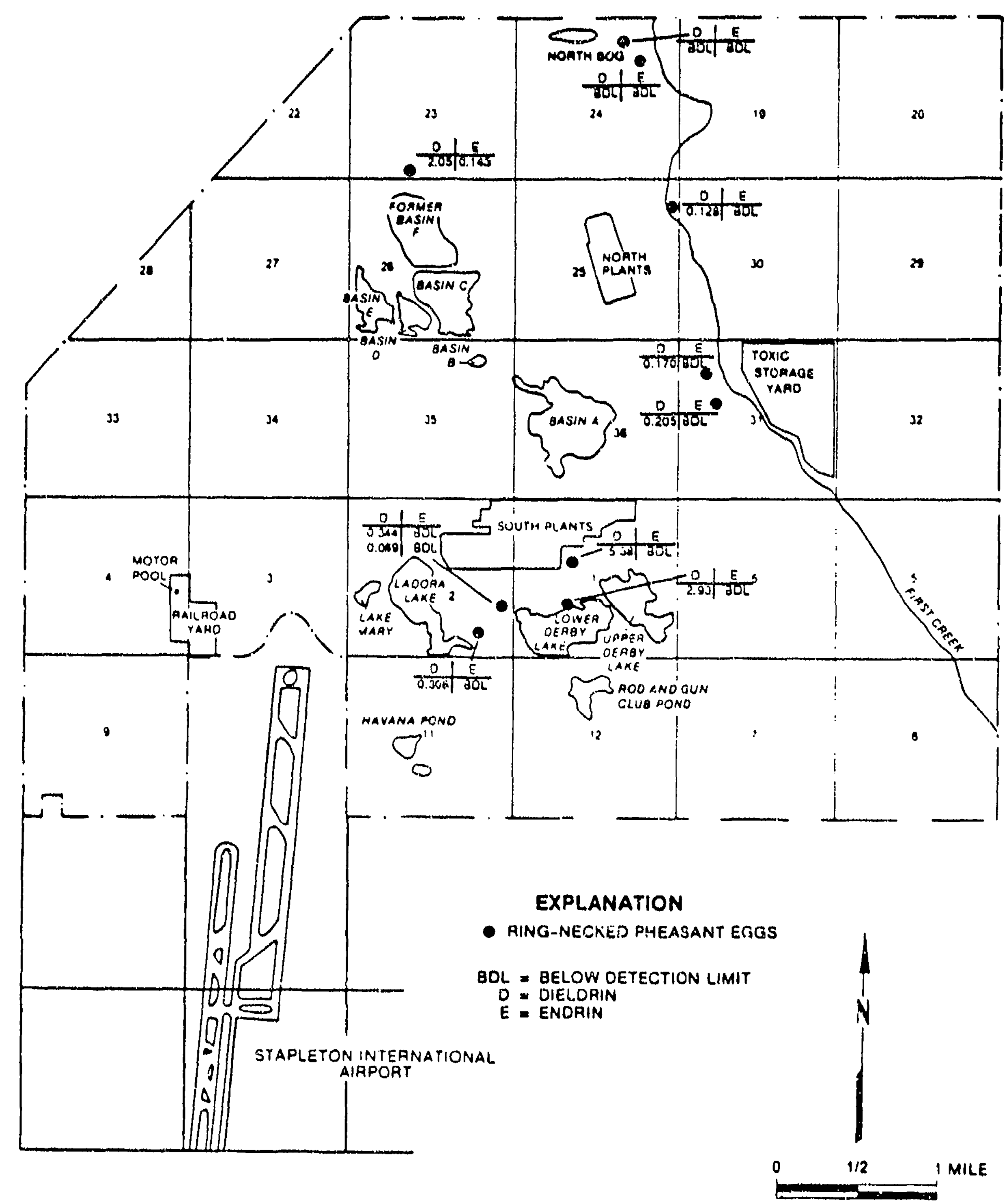

Figure 4.3-9
CONTAMINANT LEVELS IN PHEASANT EGGS FROM RMA
SOURCE: ESE, 1986

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Aberdeen Proving Ground, Maryland

arsenic. Juveniles, both on and offpost, contained significantly higher levels of arsenic. No adult or egg samples contained any detectable arsenic. In contrast, significant differences between control and RMA sites for eggs and juveniles (but not adults, probably due to small sample size) were obtained for dieldrin. The preliminary ANOVA was also significant for dieldrin.

Additional pheasants were collected at onpost and offpost locations by MKE in support of Shell investigations. Twenty individuals from RMA and two from offpost were analyzed for RMA target analytes. Muscle and liver tissue were analyzed rather than the carcass as had been done with the pheasants collected under the Biota Assessment Program. Both tissues were analyzed for organochlorine pesticides (aldrin, dieldrin, endrin, DDT and DDE), but only muscle tissue was analyzed for arsenic and mercury because of the limited amount of liver tissue available.

Two of 22 muscle tissue samples and four of six liver samples collected on RMA by MKE had concentrations of dieldrin above the certified reporting limit (CRL) (Table 4.3-2). DDE, endrin, (one hit each), and arsenic (two hits each) were also detected in pheasants from RMA. All of the samples that contained detectable contaminant concentrations were collected from interior sections of RMA. None of the tissues from pheasants collected offpost contained detectable levels of the target analytes. Contaminant levels and locations for these additional RMA pheasant samples are included in Figure 4.3-8.

Mourning Doves-- Two mourning doves found dead on the lawn of RMA headquarters (Building 111) were collected and analyzed for arsenic, mercury, aldrin, dieldrin, endrin, DDE, and DDT. Concentrations of contaminants detected in the carcass samples were <0.063 and 1.83 ppm aldrin, <0.800 and 3.44 ppm DDE, and 5.57 and 56.3 ppm dieldrin. These are the highest concentrations of dieldrin detected in any of the species analyzed and exceed FDA action limits. The liver from a third dove, collected on 7th Avenue between Sections 36 and 1, was analyzed and contained contaminant concentrations of 7.37 ppm dieldrin and 3.74 ppm endrin. No other target analytes were detected. Contaminant levels in mourning doves by RMA location are shown on Figure 4.3-7.

Cottontail Rabbits--Cottontail rabbits were collected from contaminated (Section 36) and uncontaminated areas (Sections 19, 20) on RMA and from offpost control areas; muscle tissue was analyzed. Target analytes were arsenic, mercury, aldrin, dieldrin, and endrin. DDE and DDT analysis was not required by the technical plan. No contaminants were detected in muscle tissue collected from onpost or offpost control areas, and only dieldrin was detected in samples collected from contaminated areas. Dieldrin was detected in three of seven samples at levels of 0.033, 0.048, and 0.092 ppm. Contaminant values for RMA cottontails are shown by location on Figure 4.3-10.

Statistical contrasts included comparison of onpost and offpost controls, and comparisons of pooled controls with the contaminated sites. No significant difference was observed between onpost and offpost control areas, but the a priori contrast of pooled controls and the contaminated site was significantly higher for dieldrin from the contaminated site.

Mule Deer-- Fourteen mule deer were collected on RMA and two mule deer were collected from offpost control areas. Liver and muscle tissues were analyzed for arsenic, mercury, aldrin, dieldrin, and endrin. No target analytes were detected in either tissue from control deer, and no contaminants were found in muscle tissue of deer collected on RMA. Dieldrin was detected in liver tissue of one of the 14 deer (0.187 ppm) collected onpost. No significant differences in levels of contamination in liver or muscle tissue were detected for any comparisons of control and contaminated sites. Mule deer collection sites on RMA are shown in Figure 4.3-11

Black-tailed Prairie Dog

While waterfowl, ring-necked pheasants, cottontail rabbits, jackrabbits, and small rodents are all important prey species on RMA, the most abundant prey species and the most important in relation to bald eagles wintering on RMA is the black-tailed prairie dog (ESE, 1988b, RIC#88174R03). Prairie dogs

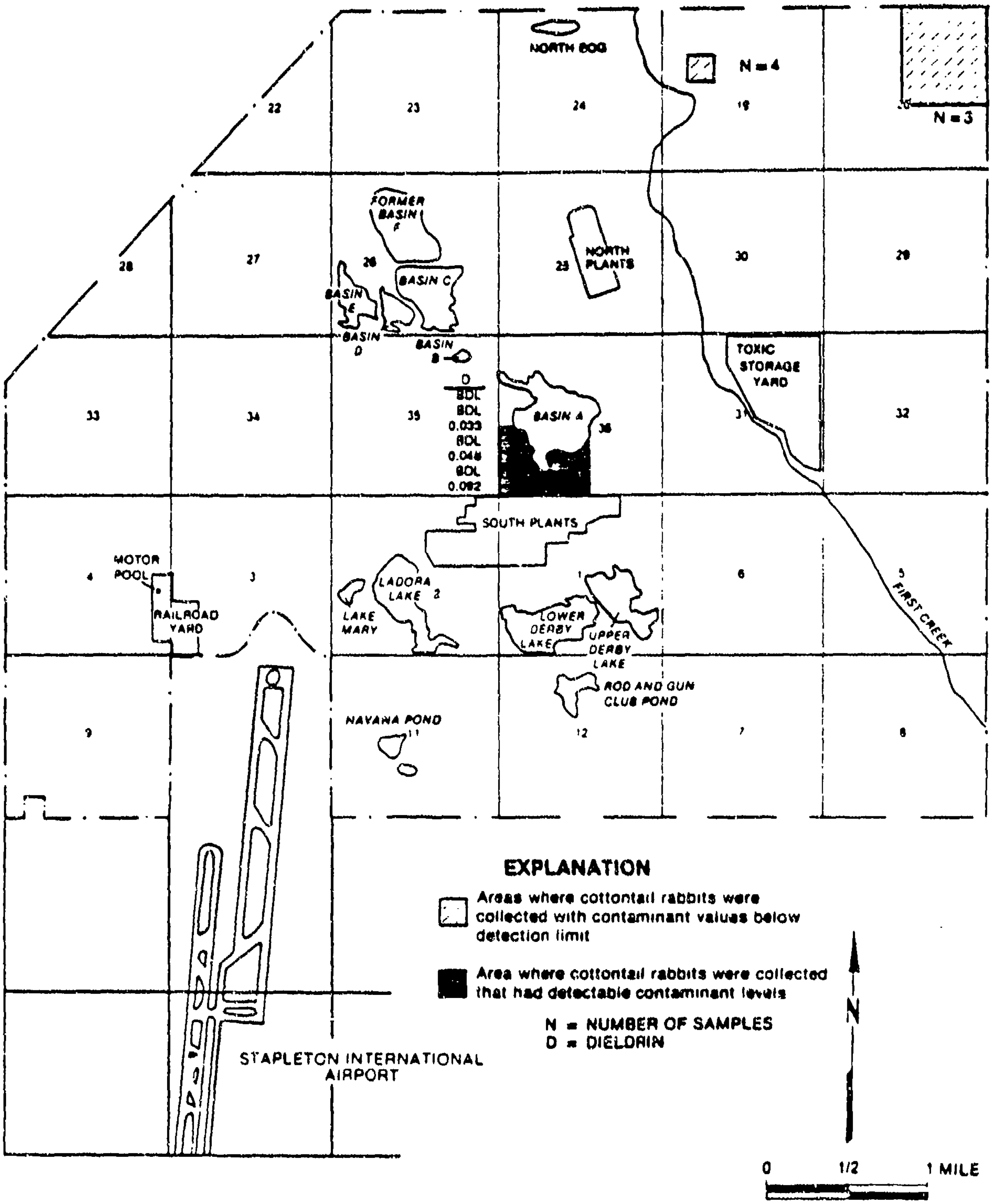

Figure 4.3-10
CONTAMINANT LEVELS OF COTTONTAIL MUSCLE TISSUE FROM RMA
SOURCE: ESE, 1988

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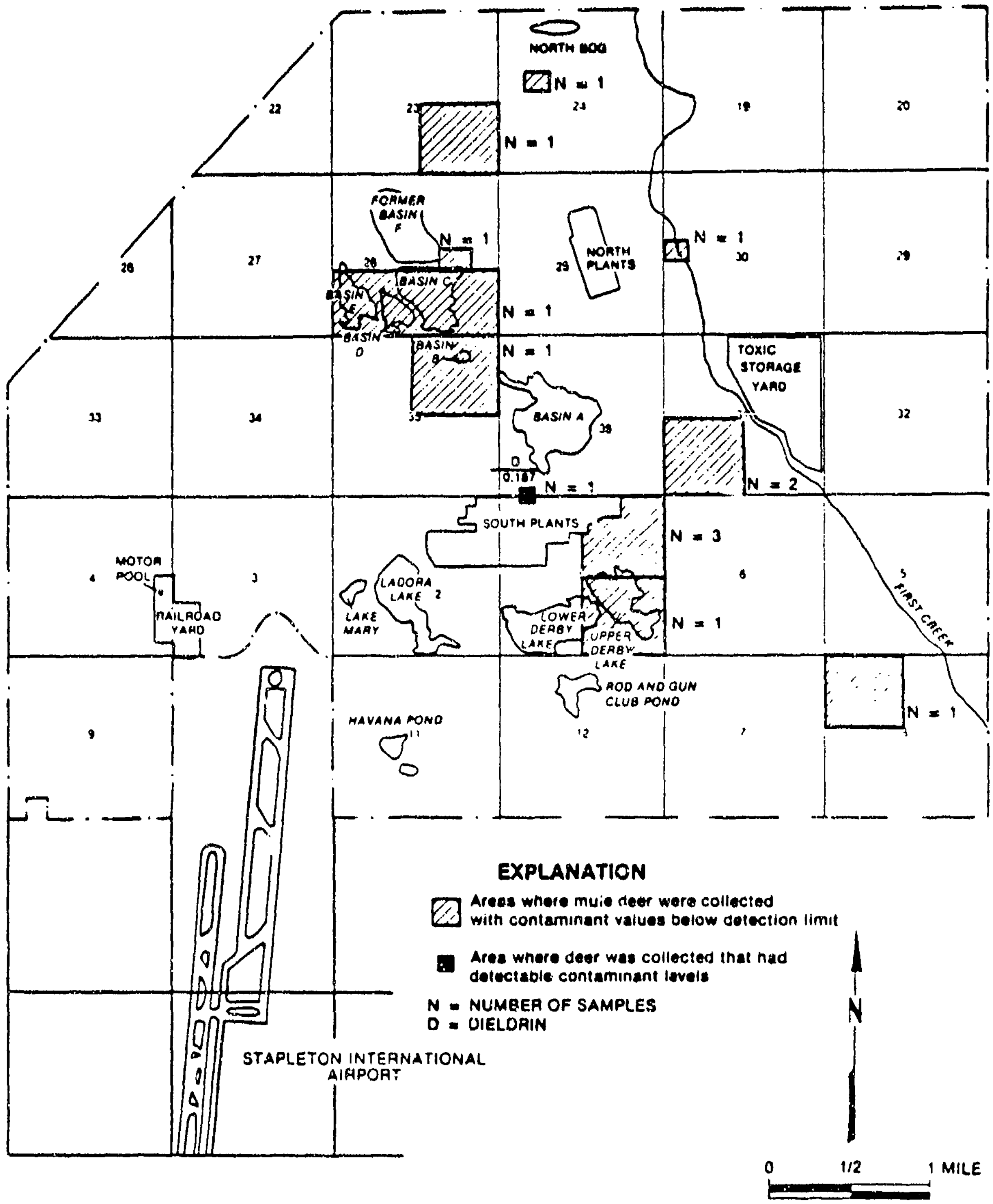

Figure 4.3-11
LOCATIONS AND CONTAMINANT LEVELS OF RMA MULE DEER
SOURCE: ESE, 1988

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

were collected for contaminant analysis during winter and summer months in order to detect any seasonal differences in contaminant levels in this prey species. Samples were collected from onpost contaminated areas (Section 36), onpost control areas (Sections 19, 20), and offpost control areas. Samples were also collected from the Toxic Storage Yard (TSY), which is an important perching and foraging area for raptors. Tissues were analyzed for arsenic, mercury, aldrin, dieldrin, and endrin. DDE and DDT analyses were not required by the technical plan. Dieldrin was detected in the tissues of prairie dogs from the TSY. Subsequent soil testing by MKE has shown that dieldrin is present in the soils near the TSY, confirming soil as the probable (state plane coordinates 2190763 East, 185264 North) source of prairie dog contamination. Arsenic and dieldrin were detected in carcasses from onpost contaminated areas, while no contaminants were detected in carcasses from offpost control areas and only dieldrin was detected in carcasses from onpost control areas.

Arsenic levels in prairie dog samples from contaminated areas were 0.478 and 0.741 ppm in two of nine samples from Section 36 in summer, all below detection limit (N = 5) from Section 36 in winter, and 4.22 ppm in one of five samples from the Toxic Storage Yard in winter. Dieldrin from contaminated areas ranged from 0.233 to 13.4 ppm (Mean = 2.03; all nine samples) from Section 36 in summer, from 0.119 to 6.18 ppm (Mean = 1.44; all five samples) from Section 36 in winter, and from 0.064 to 0.155 ppm (Mean = 0.114; all five samples) from the Toxic Storage Yard in winter. Dieldrin was detected in prairie dog carcasses in two of nine samples from onpost control areas in summer (0.064 and 0.346 ppm), in one of five samples from onpost control areas in winter (0.096 ppm), and in zero of eight samples from offpost control areas in summer. The kidneys from five prairie dogs collected from Section 36 were analyzed for arsenic, mercury, aldrin, dieldrin, and endrin. Mercury concentrations ranged from <0.10 to 0.356 ppm (Mean = 0.178). Three of the five samples contained detectable levels of mercury. Concentrations of dieldrin ranged from <0.248 to 1.54 ppm. Two of the five samples contained detectable levels of dieldrin. No other analytes were detected. Contaminant levels in prairie dogs are shown on Figure 4.3-12.

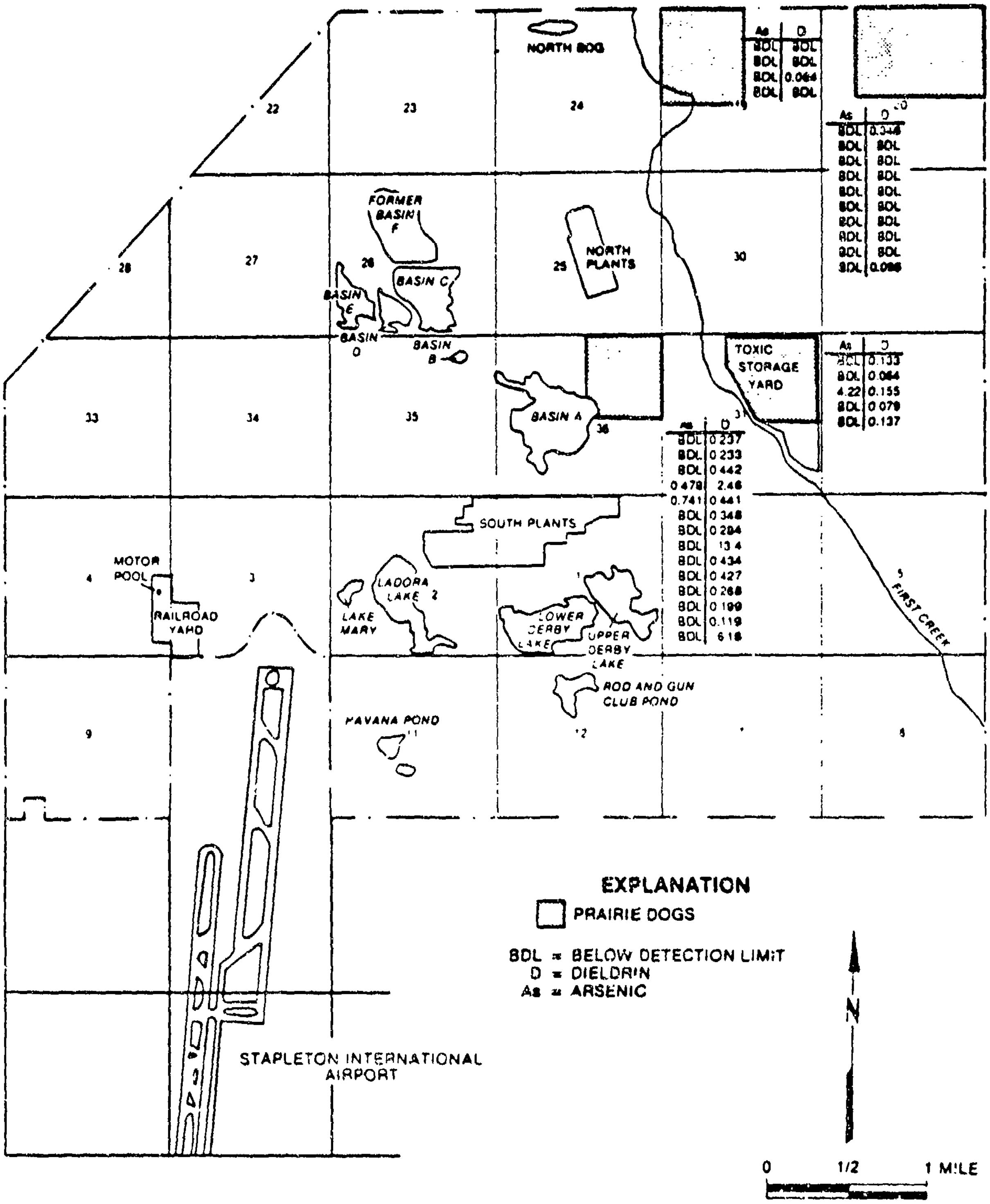

Figure 4.3-12
CONTAMINANT LEVELS OF BLACK-TAILED PRAIRIE DOG CARCASSES FROM RMA
SOURCE: ESE, 1988

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

Prairie dog samples were statistically contrasted by site and season. Seasonal differences were compared between Section 36, summer versus winter, and between onpost control areas, summer versus winter. Analysis of seasonal differences revealed that only dieldrin had significantly higher contaminant levels in summer than winter in both Section 36 and onpost control areas. All other seasonal contrasts were not significant. Section 36 (summer and winter combined) was then contrasted to the Toxic Storage Yard, while onpost control areas (summer and winter combined) were contrasted to offpost controls. A final comparison was made between pooled contaminated samples (Section 36 and the Toxic Storage Yard) and control sites (on and offpost). Dieldrin levels were significantly higher in samples from Section 36 than in samples from the Toxic Storage Yard and higher in samples from onpost controls than samples from offpost controls. Analysis of pooled samples for dieldrin revealed highly significant differences between contaminated sites and controls. Comparisons for mercury, aldrin, endrin and arsenic failed to yield any significant differences, although arsenic approached significance ($0.10 > p > 0.05$) for the comparison of pooled control sites with pooled contaminated sites.

An additional 16 black-tailed prairie dogs were collected at RMA by Shell/MKE for tissue analysis. Shell/MKE also collected four individuals at Buckley Air National Guard Base (Buckley) as an offsite comparison. Tissue analyses were conducted on two prairie dog samples from Section 26, four from Section 36, four from Section 30 north of the TSY, two from Section 27, and four from Section 9 on RMA (Figure 4.3-13). Tissue analyses were conducted on all four prairie dog samples from Buckley. Analytes were arsenic, mercury, aldrin, dieldrin, endrin, DDT, and DDE.

The only analyte present in detectable concentrations was dieldrin (Table 4.3-4). None of the four samples from Buckley showed dieldrin, while all of the samples from Sections 26, 36, 30, and 27 on RMA had reportable concentrations. None of the four samples from Section 9 on RMA, which served as an onpost control, had detectable levels of dieldrin.

These data are consistent with the data presented earlier. Particularly notable about these data are: (1) the general similarity in levels of

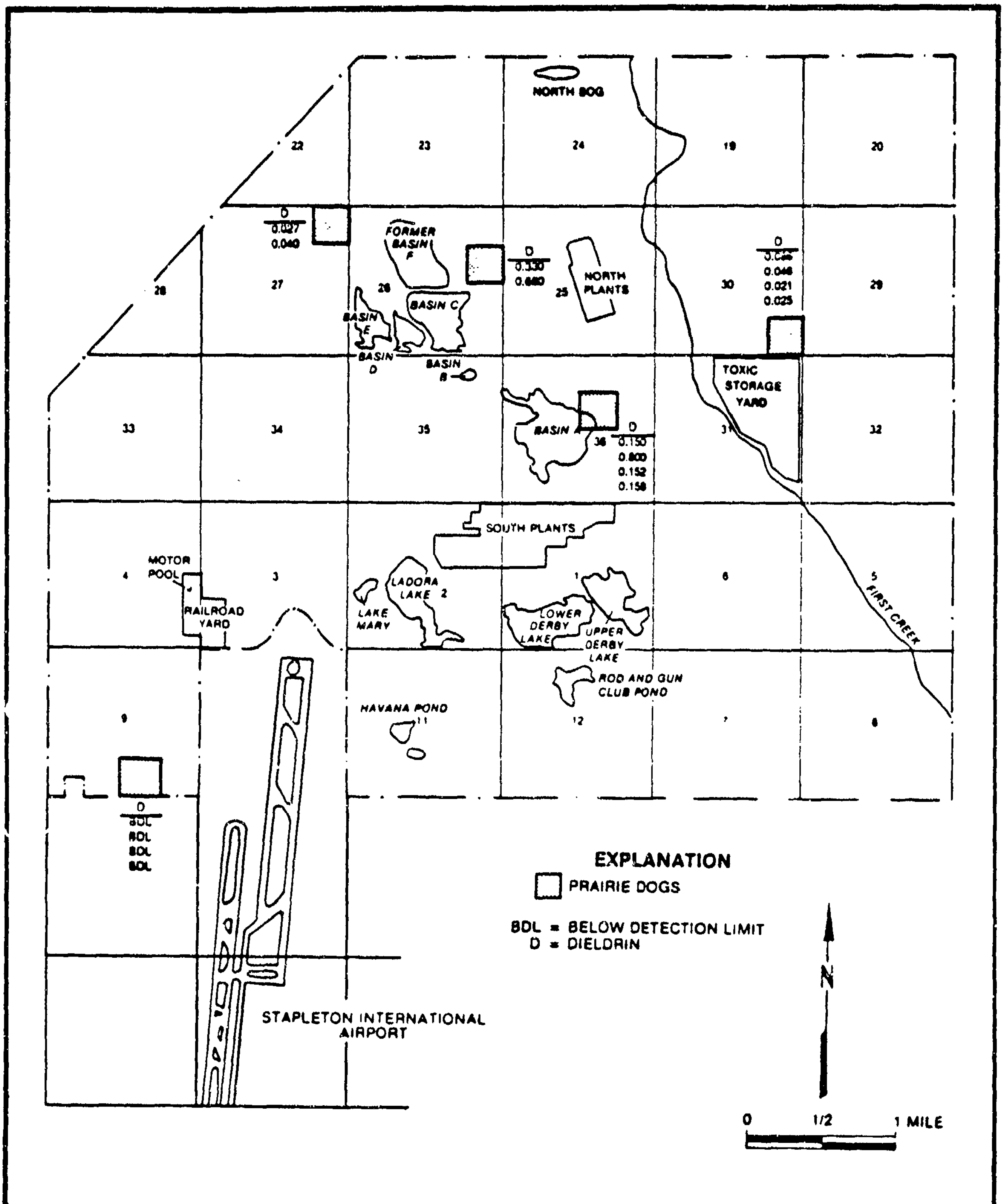

Figure 4.3-13
CONTAMINANT LEVELS OF BLACK-TAILED PRAIRIE DOGS (SKELETAL MUSCLE AND VISCERA) FROM RMA
SOURCE. ESE/MKE, 1989

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

Table 4.3-4. Contaminant Levels in Black-Tailed Prairie Dogs Collected by MKE.

Tissue	Location (Section)	Contaminant Level in parts per million (mg/kg wet weight basis)(Range/Mean*)						
		Arsenic (n/nt)	Mercury (n/nt)	Aldrin (n/nt)	Dieldrin (n/nt)	Endrin (n/nt)	p,p-DDE (n/nt)	p,p-DDT (n/nt)
Muscle and Viscera	RMA (26)	BDL (2)	BDL (2)	BDL (2)	0.33-0.66 (2/2) 0.495	BDL (2)	BDL (2)	BDL (2)
	RMA (36)	BDL (4)	BDL (4)	BDL (4)	0.150-0.800 (4/4) 0.315	BDL (4)	BDL (4)	BDL (4)
	RMA (30)	BDL (4)	BDL (4)	BDL (4)	0.021-0.086 (4/4) 0.045	BDL (4)	BDL (4)	BDL (4)
	RMA (27)	BDL (2)	BDL (2)	BDL (2)	0.027-0.040 (2/2) 0.034	BDL (2)	BDL (2)	BDL (2)
	RMA (9)	BDL (4)	BDL (4)	BDL (4)	BDL (4)	BDL (4)	BDL (4)	BDL (4)
	Buckley	BDL (4)	BDL (4)	BDL (4)	BDL (4)	BDL (4)	BDL (4)	BDL (4)

* Mean is calculated when 50 percent or more of samples have detectable contaminant levels. If less than 50 percent of samples have detectable contaminant levels, only the range of values are presented. When calculating the mean, values of ½ the detection limit are substituted for samples that are below detection limit.

BDL Below Detection Limit.

n = Number of samples analyzed that contain detectable contaminant levels, nt = total number of samples.

Source: MKE, 1988.

dieldrin from Sections 26 and 36, (2) the order-of-magnitude lower levels north of the TSY and Section 27, and (3) the absence of detectable levels of dieldrin from Section 9.

4.3.3 CONTAMINANTS IN AQUATIC ECOSYSTEMS

4.3.3.1 Documentation of Previous Contamination in Sediment and Aquatic Biota

Studies of the Lower Lakes (South Lakes) ecosystems were conducted prior to initiation of the RI by the U.S. Fish and Wildlife Service (Rosenlund et al. 1986) and the U.S. Army Engineer Waterways Experiment Station (Myers et al., 1983; Myers and Gregg, 1984).

In their 1982 study of Upper and Lower Derby lakes and Rod and Gun Club Pond, Myers et al. (1983) focused on confirming the presence, distribution, and concentration of aldrin, dieldrin, endrin, and mercury in lake sediments and adjacent inflow canals. Myers et al. (1983) found dieldrin in 100% of 44 samples from the top one foot of sediments in Lower Derby. The mean dieldrin concentration of these samples was 0.034 ug/g. Mercury was apparently analyzed in only ten of the samples. Of these, five were below the detection limit of 0.1 ug/g; the other five have a mean mercury concentration of 0.818 ug/g. The data presented by Myers et al. (1983) showed that concentrations of contaminants were highest in the upper layers, in organic materials, near the inflow channels, and in the deepest water. Lower concentrations were generally found in deeper layers of the sediments, in clastics, and in shallow water. Lower Derby Lake and the main body of Upper Derby Lake showed higher levels of the contaminants tested than the Rod and Gun Club Pond and the eastern arm of Upper Derby Lake.

A similar study of Lake Mary and Lake Ladora sediments was conducted in 1983 (Myers and Gregg 1984). This study also showed that pesticide concentrations were highest in the upper layers of sediment. Areas with highest concentrations of pesticides and mercury in Lake Ladora were the inlet channel, the "inlet pool" where the channel enters the lake, and an area near the middle of the lake. No such distinct patterns were evident for Lake Mary.

Aldrin was the most ubiquitous of the four contaminants tested by Myers and Gregg (1984), being present above the detection limit in 49 of the 50 upper layer (0-30 cm) samples (98%) and 117 of the 145 total samples (81%).

Dieldrin also was found in 98% of the upper layer sediments, but fewer (64%) of the total samples. Endrin was detected in only 58% of the upper layer and 34% of the total samples. Mercury was present in 91 of the 145 total samples (63%) and was uniformly distributed throughout the 91.5 cm of bottom material collected. Mean concentrations reported by Myers and Gregg (1984) for the upper layer of sediments in lakes Mary and Ladora were as follows (maximum values are shown in parentheses): aldrin--0.0053 ppm (1.70 ppm); dieldrin--0.0051 ppm (0.110 ppm); and mercury--0.15 ppm (2.22 pm). In all cases, means were calculated by assigning half the detection limit to BDL values. Detection limits were 0.0002 ppm for the pesticides and 0.1 ppm for mercury.

Analyses by Rosenlund et al. (1986) of water samples from Lower Derby Lake, Lake Ladora, and Lake Mary revealed no values above detection limits for aldrin, dieldrin, endrin, or mercury. Detection limits were in the parts per billion range for mercury and tenths of a part per billion range for organochlorine pesticides. Similar results had been obtained in 1983 by Bergerson et al. (1984). Myers and Gregg (1984) found dieldrin at a concentration of 0.02 ppb in a sample of water from Lake Mary, but not from Lake Ladora. Their study of Upper and Lower Derby Lakes (Myers et al. 1983) did not include water samples.

The Rosenlund et al. (1986) studies addressed lakes Mary, Ladora, and Lower Derby. Organisms sampled included six fish species--northern pike, largemouth bass, bluegill, black bullhead, channel catfish, and carp; two amphibians--bullfrogs and "toads"; five groups of aquatic invertebrates--dragonflies, damselflies, chironomids, crayfish, and snails; plankton (including both phytoplankton and zooplankton); and four species of aquatic macrophytes--American pondweed, leafy pondweed, northern water-milfoil, and coontail. Sampling was conducted five times during 1984 in order to determine any seasonal variations. Each lake was divided into quarters for sampling, and four areal subsamples were recombined ("pooled") to provide a single composite sample for each lake.

Results of the Rosenlund et al. (1986) studies are described in the following subsections, organized by lake and contaminant. Discussions of their findings are followed by summaries of studies conducted by Shell/MKE in 1986 and 1988.

The 1986 Shell/MKE sampling program included aquatic plants, plankton, and fish. The locations and number of samples collected were as follows: composite phyto-zooplankton samples from Lake Mary (n = 3), Lake Ladora (n = [illegible]), Lower Derby Lake (n = 3), and North Bog (n = 3); aquatic [illegible] (pondweeds) from Lakes Mary and Ladora (two samples each); whole [illegible] from Lakes Mary, Lower Derby, and Ladora (three samples each); [illegible] bass fillets from Lake Mary (n = 2); whole bluegill from [illegible] (n = 3) and Lower Derby (n = 3); bluegill [illegible] northern pike fillets from Lake Ladora and [illegible] (respectively); whole black bullhead from Lower [illegible] composite sample of fathead minnows from North [illegible]

The [illegible] Shell/MKE aquatic sampling program included whole largemouth bass from McKay Lake (offpost control) and Lower Derby (five samples each); whole bluegill from McKay Lake (n = 2) and Lower Derby (n = 5); bass fillets and remains from McKay Lake and Lower Derby (five samples each); and bluegill fillets and remains from McKay Lake and Lower Derby (five samples each).

Table 4.3-5 presents the results of tissue analyses performed on aquatic biota samples collected during the RI in 1986 and 1988. As described more fully in Section 4.3.3.5, the 1986 program emphasized comparisons among lakes, species, and tissue types on RMA, while 1988 program was directed primarily at onpost-offpost comparisons.

4.3.3.2 Contamination in Aquatic Biota in Lower Derby Lake

Aldrin--Rosenlund et al. (1984 data) reported that 72% of the 47 samples of biota analyzed for aldrin were above the detection limit. Organisms with detectable concentrations of aldrin included pondweeds, pike, bass, bluegill, young-of-year bullhead catfish, carp, chironomid insect larvae, and plankton. Mean aldrin levels were greatest in bass viscera (0.30 ppm), followed by pike viscera (0.174 ppm), plankton (0.153 ppm), and chironomids

Table 4.3-5. Contaminant Levels in Aquatic Ecosystems (page 1 of 2).

SPECIES	Tissue	Location	Contaminant Level in parts per million (mg/kg wet weight basis) (Range/mean*)						
			Arsenic (n/nt)	Mercury (n/nt)	Aldrin (n/nt)	Dieldrin (n/nt)	Endrin (n/nt)	DDE (n/nt)	p,p'-DDT (n)
AQUATIC PLANTS AND PLANKTON									
Plankton	Composite	RMA Lake Mary, 1986	<0.250-0.432 (1/3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)
	Composite	RMA Lake Ladora, 1986	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)
	Composite	RMA Lower Derby, 1986	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)
	Composite	RMA North Bog, 1986	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)
Aquatic Macrophytes	Whole	RMA Lake Mary, 1986	0.465-0.782 (2/2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)
	Whole	RMA Lake Ladora, 1986	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)
	Whole	RMA Lower Derby, 1986	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)
FISH									
Largemouth Bass	Fillet	Offpost Control 1988	BDL (5)	0.111-0.236 0.152 (5/5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)
	Remainder	Offpost Control 1988	BDL (5)	0.058-0.120 0.084 (5/5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)
	Compos. Whole	Offpost Control 1988	BDL (1)	0.084 (1)	BDL (1)	BDL (1)	BDL (1)	BDL (1)	BDL (1)
	Whole(Reconst.)	Offpost Control 1988	BDL (5)	0.086-0.157 0.109 (5/5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)
Largemouth Bass	Fillet	RMA Lower Derby 1988	BDL (5)	0.176-0.550 0.369 (5/5)	<0.020-0.044 (1/5)	<0.031-0.370 0.212 (4/5)	BDL (5)	<0.094-0.684 0.319 (4/5)	BDL (5)
	Remainder	RMA Lower Derby 1988	BDL (5)	0.190-0.319 0.250 (5/5)	<0.020-0.053 0.031 (4/5)	0.100-0.860 0.486 (5/5)	BDL (5)	0.101-0.839 0.593 (5/5)	BDL (5)
	Compos. Whole	RMA Lower Derby 1988	BDL (1)	0.098 (1)	BDL (1)	BDL (1)	BDL (1)	BDL (1)	BDL (1)
	Whole(Reconst.)	RMA Lower Derby 1988	BDL (5)	0.183-0.394 0.294 (5/5)	BDL (5)	0.067-0.644 0.375 (5/5)	BDL (5)	BDL (5)	BDL (5)
Largemouth Bass	Whole	RMA Lake Mary, 1986	BDL (3)	<0.050-0.101 0.066 (2/3)	BDL (3)	<0.031-0.115 (1/3)	BDL (3)	BDL (3)	BDL (3)
	Fillet	RMA Lake Mary, 1986	BDL (2)	<0.050-0.101 (1/2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)
	Whole	RMA Lake Ladora, 1986	BDL (3)	0.084-0.235 0.182 (3/3)	BDL (3)	<0.031-0.034 0.027 (2/3)	BDL (3)	BDL (3)	BDL (3)
Largemouth Bass	Whole	RMA Lower Derby, 1986	BDL (3)	<0.050-0.063 (1/3)	BDL (3)	<0.031-0.112 0.072 (2/3)	BDL (3)	BDL (3)	BDL (3)

Table 4.3-5. Contaminant Levels in Aquatic Ecosystems (page 2 of 2).

SPECIES	Tissue	Location	Arsenic (n/nt)	Mercury (n/nt)	Aldrin (n/nt)	Dieldrin (n/nt)	Endrin (n/nt)	DDE (n/nt)	p,p'-DDT (n/nt)
			Contaminant Level in parts per million (mg/kg wet weight basis) (Range/mean*)						
Bluegill	Fillet	RMA Lake Mary, 1986	BDL (3)	<0.050-0.099 0.074 (2/3)	BDL (3)	<0.031-0.041 (1/3)	BDL (3)	BDL (3)	BDL (3)
	Whole	RMA Lake Mary, 1986	BDL (6)	<0.050-0.137 0.061 (3/6)	BDL (6)	<0.031-0.158 0.085 (5/6)	BDL (6)	BDL (6)	BDL (6)
Bluegill	Whole	RMA Lower Derby, 1988	BDL (6)	<0.050-0.091 0.056 (3/6)	BDL (6)	<0.031-0.129 0.074 (4/6)	BDL (6)	BDL (6)	BDL (6)
	Whole	RMA Lower Derby, 1986	BDL (3)	BDL (3)	BDL (3)	0.142-0.161 0.149 (3/3)	BDL (3)	BDL (3)	BDL (3)
Bluegill	Whole	RMA Lake Ladora, 1986	BDL (3)	0.059-0.124 0.084 (3/3)	BDL (3)	0.065-0.153 0.100 (3/3)	BDL (3)	BDL (3)	BDL (3)
Bluegill	Fillet	Offpost Control, 1988	BDL (5)	0.081-0.256 0.188 (5/5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)
	Remainder	Offpost Control, 1988	BDL (5)	<0.050-0.171 0.104 (4/5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)
	Compos.(Whole)	Offpost Control, 1988	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)
	Whole(Reconst.)	Offpost Control, 1988	BDL (5)	0.088-0.178 0.141 (5/5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)
Northern Pike	Fillet	RMA Lower Derby, 1986	BDL (3)	0.278-0.470 0.405 (3/3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)
	Fillet	RMA Lake Ladora, 1986	BDL (2)	0.289-0.366 (2/2)	BDL (2)	<0.031-0.044 (1/2)	BDL (2)	BDL (2)	BDL (2)
Fathead Minnows	Composite	RMA North Bog, 1986	BDL (1)	BDL (1)	BDL (1)	BDL (1)	BDL (1)	BDL (1)	BDL (1)
Black Bullhead	Whole	RMA Lower Derby, 1986	BDL (3)	<0.050-0.052 (1/3)	BDL (3)	0.085-0.209 0.144 (3/3)	BDL (3)	<0.094-0.098 (1/3)	BDL (3)

* Mean is calculated when 50 percent or more of samples (n > 2) have detectable contaminant levels. If less than 50 percent of samples have detectable contaminant levels, only the range of values are presented. When calculating the mean, values of 1/2 the detection limit are substituted for 'BDL'.

BDL = Below Detection Limit (Below Certified Reporting Limit).

n = Number of samples analyzed that contain detectable contaminants, nt = total number of samples.

Compos. (Whole) = A number of small fish in a composite sample.

Whole (Reconst.) = A sample comprised of a portion of the fillet and remainder samples reconstituted into a 'whole' sample.

Source: MKE, 1988 and ESE, 1988.

(0.03 ppm). Mean aldrin concentrations were much lower in fillets of bass (0.009 ppm) and pike (0.005 ppm), and aldrin was not detected in crayfish, dragonflies, damselflies, bullfrogs, or toads.

Ranges of aldrin concentrations reported by Rosenlund et al. (1986) were from <0.002 to 0.017 ppm in two species of leafy pondweed, 0.040 to 0.260 ppm in plankton, and <0.002 to 0.014 ppm for fish fillets. The two bass viscera samples analyzed contained aldrin levels of 0.212 and 0.388 ppm; the four pike viscera samples ranged from 0.106 to 0.261 ppm.

Shell/MKE found no levels of aldrin above the certified reporting limits (CRL) in samples of macrophytes, plankton, black bullhead, bluegill, largemouth bass, and northern pike tissues from Lower Derby Lake in 1986. However, samples of bluegill and largemouth bass collected from Lower Derby Lake in 1988 revealed aldrin concentrations of <0.02 to 0.053 ppm in largemouth bass remains and <0.02 to 0.044 in bass fillets. This discrepancy probably is due either to differences in sampling season (fall in 1986, spring in 1988) or the size (age) of the fish analyzed.

Dieldrin--Rosenlund et al. (1984 data) reported that 85% of 47 samples of biota analyzed for dieldrin were above the detection limits. Organisms with detectable concentrations of dieldrin included pondweeds, pike, bass, bluegill, bullhead catfish, carp, crayfish, chironomids, plankton, aquatic snails, and toads. Dieldrin levels were greatest in pike and bass viscera, with ranges of 1.311 to 2.384 ppm and 4.294 to 6.500 ppm, respectively. The highest mean concentrations of dieldrin in Lower Derby aquatic biota were for the viscera of bass (5.397 ppm) and pike (1.942 ppm).

Dieldrin concentrations varied greatly among species groups in the 1984 samples from Lower Derby Lake. For example, values in fillets ranged from a low of 0.039 ppm in a pike sample to a high of 0.420 ppm in a bluegill sample. The range of dieldrin in plankton samples was slightly higher, from 0.060 to 0.500 ppm dieldrin (mean of 0.216 ppm). Leafy and American pondweed combined yielded a range of <0.004 to 0.127 ppm, with dieldrin levels in leafy pondweed generally greater than American pondweed (means of 0.059 and 0.044 ppm, respectively). Dieldrin levels for other organisms included <0.02 to 0.05 ppm in crayfish, and single sample values of 0.210 and 0.240 ppm in chironomids and toads, respectively.

Dieldrin was detected above CRLs in 67% of fish tissue samples from Lower Derby Lake in 1986 Shell/MKE studies (Table 4.3-5). Values ranged from 0.085 to 0.209 ppm in whole-body samples of black bullhead, bluegill, and largemouth bass; one of the three bass samples was below the CRL. All three northern pike fillet samples were below the CRL (no whole bodies or tissues other than fillets were analyzed for pike). Dieldrin was not detected above CRLs in macrophyte and plankton samples in 1986.

The 1988 Shell/MKE study showed dieldrin levels above the CRLs in 82% of largemouth bass tissues and 67% of bluegill samples analyzed. Bluegill whole-body concentrations of dieldrin ranged from 0.056 to 0.129 ppm. Values for largemouth bass ranged from 0.138 to 0.370 ppm in fillets and from 0.100 to 0.860 ppm in remains (whole body minus fillets). A composite of five small bass whole bodies was below the CRL. Values for "reconstructed" bass whole bodies were derived from 1988 data by recombining the concentrations in fillets and remains for individual fish. These were larger fish than those used for actual whole-body samples. The mean dieldrin concentrations for reconstructed bass whole bodies from Lower Derby Lake was 0.375 ppm (range of 0.067 to 0.644 ppm).

Endrin--Only 13% of the 47 biota samples for Lower Derby in the 1984 Rosenlund et al. study has levels above detection limits. The two groups of samples with detectable values were pike and bass viscera, with a combined concentration range of 0.040 to 0.210 ppm. Endrin was not detected above the CRL for any biota samples in the 1986 and 1988 Shell/MKE studies.

DDE--The Rosenlund et al. 1984 study did not include analysis for DDE. The Shell/MKE studies; however, did include analysis for DDE in both 1986 and 1988. In 1986, only one black bullhead whole-body showed a detectable level of DDE (0.098 ppm). In contrast, the 1988 data showed DDE above the CRL in 82% of the largemouth bass samples. DDE levels ranged from 0.182 to 0.684 ppm in fillets and from 0.101 to 0.839 ppm in remains. As with aldrin, this discrepancy may have resulted from the different sampling season or the size of the fish analyzed. DDE was not detected above CRLs in macrophyte and plankton samples in 1986.

Mercury--All of the 47 biota samples from Lower Derby Lake analyzed for mercury in the Rosenlund et al. 1984 study contained levels above the CRL. Fish fillets tended to have the highest levels of mercury, with mean concentrations of 1.90 ppm in pike fillets, 1.74 ppm in adult bullheads, 1.510 ppm in bass fillets, 0.62 ppm in 24-32 cm carp fillets, 0.58 ppm in young-of-year bullheads, and 0.51 in bluegill fillets. Mercury concentrations for other species groups (in decreasing order) were as follows: dragonflies--0.50 ppm; amphibians--0.38 ppm; crayfish--0.31 ppm; American pondweed--0.25 ppm; leafy pondweed--0.24 ppm; damselflies--0.23 ppm; plankton--0.20 ppm. Chironomids were not analyzed because of insufficient sample size.

Variation within species groups was greatest for fish fillets, which ranged from a low of 0.25 ppm for one bluegill sample to a high of 2.45 ppm for one pike replicate. Other ranges included 0.19 to 0.59 ppm for fish viscera (bass versus pike), 0.18 to 0.28 for damselflies, 0.17 to 0.42 ppm for crayfish, 0.09 to 0.31 ppm for plankton, and 0.03 to 0.18 ppm for aquatic snails.

In the Shell/MKE study, 66% of the 1986 and 1988 fish samples from Lower Derby Lake contained levels of mercury above the CRL (Table 4.3-5). Northern pike fillets analyzed in 1986 contained the highest mean concentration (0.405 ppm), followed by largemouth bass whole bodies (0.066 ppm). One of three black bullhead whole bodies showed mercury 0.0516 ppm, while all of the bluegill whole bodies was below the CRL of 0.05 ppm. In 1988, largemouth bass fillets contained mean mercury concentrations of 0.369 ppm compared to 0.250 ppm for bass remains and 0.098 for a composite of five small largemouth bass whole bodies. Reconstructed whole bodies of bass from Lower Derby Lake had a mean mercury concentration of 0.294 ppm (range of 0.183 to 0.394 ppm). Bluegill whole bodies averaged 0.056 ppm (half were below the CRL). Mercury was not detected above CRLs in macrophyte and plankton samples.

The Shell/MKE studies in 1988 included an offpost control lake (McKay Lake) for comparison with Lower Derby Lake; only bluegill and largemouth bass tissues were analyzed. All contaminants were below CRLs for McKay Lake, with the exception of mercury, which was detected above the CRL in 87% of the fish samples. Mean mercury concentrations in McKay Lake fish were as follows: bluegill fillets--0.188 ppm; bass fillets--0.152 ppm; bluegill remains--0.104 ppm; bass remains--0.084 ppm; and bass whole bodies--0.084 ppm. Mercury levels in reconstructed whole bodies (fillets plus remains) from McKay Lake ranged from 0.088 to 0.178 ppm (mean of 0.141) for bluegill, and from 0.086 to 0.157 (mean of 0.109) for bass.

4.3.3.3 Contamination in Aquatic Biota in Lake Ladora

Aldrin--Rosenlund et al. (1984 data) did not find extensive aldrin contamination in the aquatic biota sampled in Lake Ladora. Indeed, only aquatic plants, fish viscera, and one plankton sample contained concentrations above the detection limit, comprising 15% of the 51 samples. Mean aldrin concentrations were universally low, with 0.014 ppm in plankton, 0.007 ppm in aquatic plants, 0.004 ppm in bass viscera, and 0.002 ppm in bluegill viscera.

Shell/MKE found no detections of aldrin above CRLs in any aquatic biota samples from Lake Ladora in 1986 (Table 4.3-5).

Dieldrin--The Rosenlund et al. 1984 study of Lake Ladora reported dieldrin concentrations above detection limits in 86% of 51 samples. As in Lower Derby Lake samples, mean dieldrin concentrations were greatest in fish viscera, with bass (0.476 ppm) > bullheads (0.297 ppm) > bluegill (0.202 ppm). Other samples showed a pattern of plankton (0.086 ppm) > aquatic plants (0.037 ppm) > aquatic snails (0.030 ppm). Dieldrin was not above detection limits in chironomids, dragonflies, and damselflies.

Aquatic macrophytes, which represented the greatest biomass in Lake Ladora, had dieldrin concentrations ranging from 0.008 to 0.171 ppm. Viscera of fish species combined contained higher dieldrin concentrations than fillets, with ranges of 0.028 to 0.780 ppm versus 0.012 to 0.160 ppm, respectively. Plankton samples varied from 0.050 ppm to 0.130 ppm.

In the Shell/MKE 1986 analyses of fish tissues from Lake Ladora, 75% of the samples were above CRLs for dieldrin (Table 4.3-5). The mean concentrations in bluegill whole bodies was 0.100 ppm, compared to 0.027 ppm in bass whole bodies. Pike fillets had a mean concentration of 0.044 ppm. Dieldrin was not detected above CRLs in macrophyte and plankton samples.

Endrin--Endrin was detected at low levels in 8% of the 51 samples in the Rosenlund et al. 1984 study. These samples include one bluegill and one bullhead fillet at concentrations of 0.010 ppm each, and two bass viscera samples at 0.020 ppm and 0.030 ppm. Endrin was not detected during the Shell/MKE analyses of aquatic biota tissues from Lake Ladora in 1986.

Mercury--The Rosenlund et al. 1984 analyses showed that 91% of the 45 samples contained mercury above the detection limits. As in samples from Lower Derby Lake, mean mercury concentrations were highest in fish fillets, with pike (2.94 ppm) > bass (2.44 ppm) > bluegill (0.87 ppm) > bullhead (0.42 ppm). Mean mercury concentrations for other groups were as follows: plankton--0.39 ppm; aquatic plants--0.28 ppm; and dragonflies--0.123 ppm. Ranges of mercury values in fish fillets were from 0.31 ppm for one bullhead sample to 3.45 ppm for one pike sample. For viscera, values ranged from 0.04 ppm (bullhead) to 1.52 ppm (bass). No pike viscera were analyzed. Aquatic plants varied from 0.14 to 0.75 ppm, plankton from 0.05 to 0.90 ppm, and dragonflies from 0.04 to 0.17 ppm.

Shell/MKE detected mercury above CRLs in all fish samples in the 1986 study of Ladora Lake (Table 4.3-5). Values ranged from 0.059 ppm for one bluegill sample to 0.366 ppm for one pike fillet sample. Mean mercury concentrations in fish were as follows: pike fillets (0.328 ppm) > bass whole bodies (0.182) > bluegill whole bodies (0.084 ppm). Mercury was not detected above CRLs in macrophyte and plankton samples.

4.3.3.4 Contamination in Aquatic Biota in Lake Mary

Aldrin--Rosenlund et al. (1984 data) found low levels of aldrin in plankton, aquatic plants, fish fillets, and fish viscera samples from Lake Mary. Aldrin was not found above detection limits in macroinvertebrates (insect larvae) or aquatic snails. Aquatic plants--including American and leafy pondweed, northern water-milfoil, and coontail--varied in aldrin concentrations from <0.002 to 0.043 ppm. Channel catfish contained the highest mean aldrin concentrations among fish species, with a value of 0.041 ppm for the single viscera sample and 0.034 for fillet samples. Other values in fish ranged from <0.002 to 0.003 ppm for bass and bluegill. Aldrin in plankton samples ranged from <0.01 to 0.03 ppm. The Shell/MKE 1986 study of contaminants in Lake Mary detected no aldrin values above CRLs in the aquatic biota analyzed (Table 4.3-5).

Dieldrin--Dieldrin was reported above the detection limit in 79% of 47 aquatic biota samples from Lake Mary in 1984 (Rosenlund et al., 1986). The greatest concentrations of dieldrin were detected in channel catfish viscera and fillets, with mean concentrations of 0.527 and 0.402 ppm, respectively. Other concentrations were as follows: bass viscera (0.134 ppm) > bluegill fillets (0.066 ppm) > bass fillets (0.023 ppm) > plankton (0.066 ppm) > aquatic macrophytes (0.062 ppm). Dieldrin was detected at very low levels in aquatic snails (0.020 ppm) and dragonflies (<0.020 to 0.070 ppm), but not at all in chironomid or damselfly larvae. Dieldrin was detected above CRLs in 50% of fish samples analyzed by Shell/MKE in 1986 (Table 4.3-5). Detected values ranged from 0.031 to 0.158 ppm for bluegill whole-body samples, with a mean of 0.085 ppm. For bluegill fillets, dieldrin was detected in one of three samples, at 0.041 ppm. Similarly, one of three bass whole-body samples had a detectable concentration of dieldrin (0.115 ppm). Dieldrin was not detected above CRLs in macrophyte or plankton samples.

Endrin--Endrin was reported by Rosenlund et al. (1986) to be above detection limits in 15% of the aquatic biota samples collected from Lake Mary in 1984. Only two coontail samples (0.02 ppm and 0.01 ppm) were above detection limits; all other macrophytes and all invertebrates were below detection limits. Of the fish tissues analyzed, only channel catfish fillets and viscera were greater than the 0.01 ppm detection limit, with endrin concentrations of 0.05 and 0.06 ppm, respectively.

Endrin values were below the CRLs from analysis of all aquatic biota during the Shell/MKE 1986 study of Lake Mary.

Mercury--Rosenlund et al. (1984 data) detected mercury in 92% of aquatic biota samples analyzed. Mean mercury concentrations in fish were as follows: bluegill fillets (0.51 ppm) > bass fillets (0.50 ppm) > catfish fillets (0.28 ppm). Values for viscera were 0.34 ppm for bass and 0.12 ppm for catfish. Mercury concentrations in other species groups were 0.25 ppm for macrophytes, 0.21 ppm for damselflies, 0.19 ppm for plankton, and 0.176 ppm for dragonflies, and 0.04 for chironomids. Mercury was not detected in the single sample of aquatic snails. In their 1986 study, Shell/MKE found mercury above the CRL in 57% of bluegill and bass tissue samples (Table 4.3-5). Mean concentrations were similar, with the following trend: bluegill fillets (0.074 ppm) > bass fillet (0.101 ppm) > bass whole bodies (0.066 ppm) > bluegill whole bodies (0.061 ppm). Mercury was not detected above CRLs in macrophyte or plankton samples.

Arsenic--Shell/MKE 1986 studies of Lake Mary detected arsenic above CRLs in both macrophyte samples (0.782 and 0.465 ppm), as well as one plankton sample (0.432 ppm) (Table 4.3-5). Arsenic was not detected above CRLs in any other aquatic biota for all RMA lakes.

4.3.3.5 Statistical Review of Biotic Contaminant Data

In their 1984 study of aquatic biota contamination at RMA, Rosenlund et al. (1986) used analysis of variance (ANOVA) to test for statistical significance of differences among lakes as well as temporal and species-specific differences within lakes.

The Rosenlund et al. analyses in 1984 of aldrin, dieldrin, and mercury in aquatic macrophytes (plants) showed no statistically significant ($p < 0.05$) differences among lakes. However, some species-specific significant differences within lakes were reported. In Lower Derby Lake, differences in dieldrin concentrations were highly significant ($p < 0.001$) between leafy and American pondweed, with mean values of 0.078 ppm and 0.044 ppm, respectively. Differences between these two macrophytes in Lower Derby Lake were also significant ($p < 0.01$) for aldrin, with concentrations in leafy and American pondweed of 0.009 ppm and 0.003 ppm, respectively.

For macrophytes in Lake Ladora, Rosenlund et al. (1986) reported that dieldrin concentrations were significantly different ($p < 0.05$) among four species, with means (in ppm) as follows: leafy pondweed (0.108) > American pondweed (0.036) > coontail (0.017) > water-milfoil (0.010). The same trend was evident in Lake Mary, where differences in dieldrin among macrophytes approached significance ($p < 0.10$). Mean values (in ppm) in Lake Mary were as follows: leafy pondweed (0.26) > American pondweed (0.055) > coontail (0.027) > water-milfoil (0.010).

For plankton (including both phytoplankton and zooplankton), Rosenlund et al. (1986) reported significantly higher concentrations of aldrin and dieldrin in Lower Derby Lake than the other lakes. Monthly variations within lakes approached significance for mercury but not for the pesticides.

For samples of fish tissue, Rosenlund et al. (1986) reported that aldrin in pike and bass fillets was significantly higher for Lower Derby Lake than either lakes Ladora or Mary. Higher values of aldrin in Lower Derby approached significance for bass viscera and black bullhead fillets. Dieldrin was significantly higher in both bass fillets and viscera from Lower Derby than from the other lakes. Differences in mercury concentrations among the three lakes were highly significant ($p < 0.001$) for bass fillets, with Ladora > Lower Derby > Mary.

Statistical analyses were also performed on aquatic tissue data collected by Shell/MKE in 1986 and 1988 (see Appendix B, Section 3.0). Two different statistical approaches were employed. Fifteen complete tests, each holding experiment-wise error rate constant at 0.05 and including a priori orthogonal contrasts, constitute the "primary" design. As a result, 30 pair-wise comparisons of groups composed our orthogonal a priori contrasts, based upon the nonparametric results. For every complete test, an analogous parametric test was also ran for comparative purposes. "Secondary tests"

(31 total) were more exploratory, using numerous pair-wise comparisons (t-tests and one-way ANOVAs) that did not conform to this rationale, and were performed by MKE to search for differences among analagous data sets (lakes, species, and tissues).

Results of primary tests revealed nine significant contrasts as well as three contrasts approaching significance.

Significant Contrasts (Primary Tests)

1. Between Derby and McKay Lakes for remains in largemouth bass in 1988 for mercury.
2. Between Derby and McKay Lakes for fillets in largemouth bass in 1988 for mercury.
3. Between Derby and McKay Lakes for remains in largemouth bass in 1988 for dieldrin.
4. Between Derby and McKay Lakes for fillets in largemouth bass in 1988 for dieldrin.
5. Between Derby and McKay Lakes for remains in largemouth bass in 1988 for DDE.
6. Between Derby and McKay Lakes for fillets in largemouth bass in 1988 for DDE.
7. Between Derby and McKay Lakes for remains in largemouth bass in 1988 for aldrin.
8. Between Derby and McKay Lakes for whole tissues in largemouth bass in 1988 for mercury.
9. Between bluegill and bass (with data pooled for Lakes Derby and McKay) for whole tissues in 1988 for mercury.

Approaching Significant Contrasts (Primary Tests)

10. Between remains and fillets for Lake McKay in 1988 for mercury in bluegills.
11. Among lakes (Derby vs Ladora vs Mary) for whole tissues in 1986 for largemouth bass for mercury.
12. Between bass and bluegill (with data pooled from lakes Derby, Ladora, and McKay) for whole tissues in 1986 for dieldrin.

The secondary tests revealed 10 contrasts which at least approached significant (based upon nonparametric results). Half of these (5) confirmed the primary tests and were, in fact, mathematically equivalent to them. Five potential ares of effect were not discovered in the primary tests because they could not be addressed within the framework of a constant experiment-wise error rate held at 0.05. They appear hereafter.

Significant Contrasts (Secondary Tests)

1. Between bass and bluegill for whole body in 1986 for dieldrin.
2. Between bass and bluegill (where bass are reconstructed samples) for whole body in Lake Derby for 1988 for mercury.
3. Between or bass and bluegill whole body in Lake Derby for 1988 for dieldrin.
4. Between bass and bluegill for whole body in Lake Ladora for 1986 for dieldrin.
5. Between fillets and remains for bass from Lake McKay in 1988 for mercury.

Statistical comparisons between an onpost lake (Lower Derby) and an offpost control lake (McKay) were made using data from 1988 (samples collected on successive days). These statistical analyses revealed significantly higher concentrations of dieldrin, aldrin, and DDE onpost than offpost for bass, but not for bluegill. None of these pesticides were detected in any of the offpost samples, whereas they were widespread in the onpost samples. These comparisons (i.e., with no detected values in the offpost data set) were made using a nonparametric ANOVA by ranks. Parametric tests were not performed because of zero variance associated with the offpost data set (i.e., all values below certified reporting limits). Mercury, which was detected in both onpost and offpost samples from 1988, was significantly higher onpost in bass remains, fillets, and whole bodies. The mercury concentrations in bluegill whole bodies were higher in Lower Derby Lake than in Lake McKay, with a difference which approached statistical significance.

Tissue concentrations in some cases are related to the sizes of the fish sampled. Weights of individual bass and bluegill analyzed in 1986 and 1988, and their corresponding dieldrin and mercury concentrations, are shown in Table 4.3-6.

MKE calculated condition factor (K) based on fish length and weight data to compare McKay Lake with the RMA lakes for two size classes of these two species. For small bluegills, the mean condition factor at McKay Lake was significantly lower than the values at any of the RMA lakes. For large bluegills, the mean condition factor at McKay was identical to that in Lake Ladora, and significantly lower than the values in Lake Mary and Lower Derby Lake. The mean condition factor for small largemouth bass was not significantly different among the lakes. For large largemouth bass, the mean condition factor was significantly lower in Lake Mary than in the other lakes.

Table 4.3-6. Nonstatistical Comparisons of Mercury and Dieldrin Concentrations for Individual Bass and Bluegill Whole Bodies in Relation to Weight

Species	Lake	Weight (g)	Mercury (ppm)	Dieldrin (ppm)
Bass (1986)	Lower Derby	37.30	<0.05	0.112
		37.46	0.063	<0.031
		37.60	<0.05	0.088
Bass (1988)	Lower Derby	483.33	0.183	0.668
		1,835.10	0.312	0.286
		1,959.88	0.394	0.481
		2,153.24	0.275	0.396
		2,251.62	0.306	0.644
Bluegill (1986)	Lower Derby	31.58	<0.05	0.161
		37.66	<0.05	0.143
		40.84	<0.05	0.142
Bluegill (1988)	Lower Derby	53.30	0.091	0.056
		64.27	0.063	0.129
		78.44	<0.05	0.098
		89.35	0.074	<0.031
		90.16	<0.05	0.074
Bass (1986)	Ladora	63.66	0.235	0.032
		67.67	0.084	<0.031
		88.08	0.228	0.034
Bluegill (1986)	Ladora	34.37	0.124	0.083
		81.73	0.069	0.064
		87.37	0.059	0.153
Bass (1986)	Mary	93.96	0.072	<0.031
		96.35	0.101	<0.031
		218.28	<0.05	0.115
Bluegill (1986)	Mary	76.70	<0.05	0.158
		76.92	<0.05	0.100
		98.81	0.062	0.094
		100.47	0.092	<0.031
		100.81	<0.05	0.107
		125.10	0.137	0.038
Bass (1988)	McKay	248.79	0.122	<0.031
		291.18	0.086	<0.031
		304.19	0.086	<0.031
		437.85	0.092	<0.031
		1,177.71	0.157	<0.031
Bluegill (1988)	McKay	94.75	0.173	<0.031
		101.90	0.178	<0.031
		106.11	0.134	<0.031
		106.91	0.088	<0.031
		112.58	0.130	<0.031